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National SPE officers for 1953 are (left to right) TREASURER Richard Bruce, (Bakelite Co.), PRESIDENT Walter Oelman (Standard Molding Corp.), VICE-PRESIDENT Stanley Bindman, (Jamison Plastics), and SECRETARY John LaBelle (Koppers).

PUBLISHED BY THE SOCIETY OF PLASTICS ENGINEERS, INC.

1100 Attend SPE Ninth Conference

THE SPE NATIONAL COUNCIL in session in Boston the day before the Ninth SPE Conference. (Clockwise around left table starting at left front) Islyn Thomas, Newark; Joe Healey, membership chairman; Jerome Formo, Upper Midwest; Frank Reinhart, Baltimore-Washington; Haiman Nathan, Buffalo; Richard Bishop, Philadelphia; Emil Gazdick, Detroit; Lee Swift, Chicago; Ned Porter, publicity; (Back table left to right) William Bracken, retiring president; Stanley Bindman, 1953 national vice-president, New York; Walter Oelman, 1953 national president, Miami Valley; Bess Day, executive-secretary; John LaBelle, 1953 national secretary, Eastern New England; (Right-hand table left to right) John Mallory, Western New England; Gerald Delaire, Rochester; Charles Seay, Ontario; Richard Bruce, 1953 national treasurer Rhode Island and S.E. Mass.; George Fields, Cleveland; and John Chomicz, Southeastern Ohio.

Boston drew over 1100 people to the Ninth Annual SPE Conference. This is almost 50% bigger than previous Conferences, and we think reflects the very real growth in stature of the SPE in the past year. And the smoothness with which the Conference goes improves each year with the accumulated experience of the Conference committees being passed on to the next group.

Ninety-four new members were signed up at the Conence! Joe Healey, who really enjoys selling a superior product, was stationed opposite the registration desk with a supply of application blanks, ready to discuss SPE membership advantages with non-member registrants. SPE extends warm thanks to Joe Healey (Manco Products) and a warm welcome to the new members.

The National Council met the day before the Conference, and transacted business, first of which was the election of National Officers for 1953:

President: Walter Oelman, Standard Molding Corp., Dayton, Ohio. Mr. Oelman was secretary in 1951 and vice president last year.

Vice-President: Stanley Bindman, Jamison Plastics Corp., New York, N. Y. Mr. Bindman has served as section news editor for the past few months.

Secretary: John LaBelle, Koppers Co., Inc. Mr. LaBelle was secretary last year and was chairman of the 1953 conference committee.

Treasurer: Richard Bruce, Bakelite Co., Hartford, Conn. Mr. Bruce served on the Executive Committee last year and has been very active in the New England area.

Sites of the SPE Conferences through 1959 have been chosen. It may seem surprising, but plans must be laid at **least** three years ahead, if only for the reason that first-class hotels capable of handling an SPE Conference are booked up that far in advance and some are booked up as much as 5 years in advance! The plan is to have the Conferences distributed as equitably as possible about the country. The Tenth Annual SPE Conference is set for Toronto, Canada, Jan. 27-29, 1954, at the Royal York Hotel. The Toronto Conference Committee is already hard at work.

Future meetings are planned as follows: 1955 Philadelphia, 1956 Cleveland, 1957 St. Louis, 1958 Detroit, 1959 New York.

Concurrent sessions of technical papers extended over two and a half days of the Conference, with Friday afternoon devoted to a panel discussion composed of all the speakers, following the luncheon. Luncheon speaker General Doriot, attributed the great rise in the use of plastics in the last decade to a decision of William Knudsen early in World War II to cut back sharply on permitted uses for copper and tin, which made the government agencies seek among the plastics materials substitute materials for such things as canteens and other supplies. Doriot further cautioned the plastics industry that sound engineering and careful planning are necessary to continued health of the plastics business.

APPLICATIONS FOR MEMBERSHIP AT CONFERENCE IN BOSTON

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(Continued on page 4)

JOURNAL

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INDEX

Winners in the 1952 SPE Prize Paper Contest

1st prize——The Basic Principles of the Injection Molding Process—C. E. Beyer and R. B. Dahl 6

2nd prize—A New Process for the Manufacture of Furfural Alcohol Resin Intermediates—Erik R. Nielsen 10

3rd prize—Injection Molding of Elastomeric Vinyl—Materials—Frank A. Martin 12

Honorable Mention—The Compounding and Processing of Rigid Polyvinyl-Chloride—Robert J. Ettinger 16

ARTICLES

Triallyl Cyanurate in the Preparation of Heat Resistant Resins—H. M. Day and J. G. Affleck 22

Electrostatic Properties of Rubber and Plastics—H. A. Endres and Ward T. VanOrman 26

Tomorrow's Roll Surface Temperature Control and New Press Heating Systems—Paul Geiringer 32

Techniques of Injection and Compression Molding of Polytrifluorochloroethylene—Carmen R. Giannota 38

Vinyl Floor Coverings—R. K. Petry 36

FEATURES

The Injection Molderscope—A. R. Morse 56

Plastics Around the World 45

News of the Sections 52

ADVERTISERS

Bakelite Co., Div. of Union Carbide and Carbon Corp. 31

A. Bamberger, Corp. 50

Barrier-Pribble and Co., Inc. 53

Durez Plastics and Chemicals Co. 59

Industrial Manufacturing Corp. 58

International Business Machines 60

Injection Molder's Supply Co. 50, 58

Manco Products, Inc. 54

Metasap Chemical Co. 4

Monsanto Chemicals and Plastics 5

Stocling, Inc. 60

The Society of Plastics Engineers Journal is not responsible for the views expressed by individual contributors. Copy for each issue should be received at The Security Bank Bldg., Athens, Ohio, before the 25th of the preceding month.

Across the Editor's Desk

● Abstracters are needed for the following magazines: Plastiques Informations (French), Materie Plastiche (Italian), Plastic (Danish), Plasticos (Spanish, from Argentina), Revista de Plasticos (Spanish), and Matieres Plastiques et Resines Synthetiques (French). In printing abstracts from the foreign journals, SPE Journal's "Plastics Around the World" is performing a vital and necessary service to the whole plastics industry. Here's a chance to take an important part in the SPE. If you'd like to abstract one of these publications, write to the Editor, SPE Journal, Security Bank Bldg., Athens, Ohio.

● Plastics information appears in a great many places, and the SPE Journal series on Plastics Know-How is an attempt to define the plastics literature, and tell where it can be found. First in the series covered the current plastics magazines, and appeared in the January issue. Second in the series deals with plastics information in government reports, by Wolock and Kanegis, and will appear in the March issue. We still need an author to undertake an article on the various company publications in the United States. Anyone interested?

● National publicity committee is headed by Ned Porte, Chicago Section. Each Section has a local publicity committee. To keep track of the publicity gained by the SPE, we would like to receive clippings of all printed references to SPE and its activities. We are asking for one or two volunteers in each Section to send in a copy of any or all clippings referring to the SPE.

● Among the telegrams reaching the Conference was one of congratulations and best wishes from the German plastics industry, sent by Dr. Roehn Eos, Frankfurt.

● Here's more information on three of the publications listed in "Plastics Know-How" in the January issue of the Journal.

SVENSKA PLAST FORENINGEN have three publications, all mimeographed on 8½" x 13" paper. The **Tekniska Meddelanden** is circulated to the SPF membership about 48 times a year. This series has the papers read at the Spring and Fall meetings of the Federation, and translations from foreign publications. The **Plastforeningen Meddelar** is published every month, deals with activities of the Federation, activities of member companies, and news of the industry in Sweden and abroad. The **Manadens Litteraturtips** is a combined abstract and reference service on the current literature, taken from the about 190 various periodicals on plastics and allied products. All these publications are distributed to the membership of the Swedish Plastics Federation plus various foreign plastics industry organizations; thus there is no subscription price as such. Inquiries can be addressed to Jan-Erik Janson, Executive Secretary, Svenska Plast Foreningen, 43 Karlavagen, Stockholm, Sweden.

THE PLASTICS NEWSLETTER (Australia), issues from The Plastic Institute of Australia, Steamship Building, 17 Currie St., Adelaide, South Australia.

REVISTA DE PLASTICOS, published from the Instituto "Alonso Barba," Serrano, 119, Madrid, Spain, bimonthly, annual subscription 80 pts. The November-December 1952 issue is Vol. 3, No. 18, has 70 pages, 8½" x 12¼". Contains beside usual technical articles and industry news, a list of selected abstracts. Photocopies of any of the articles abstracted are available to subscribers.

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(Continued from page 2)

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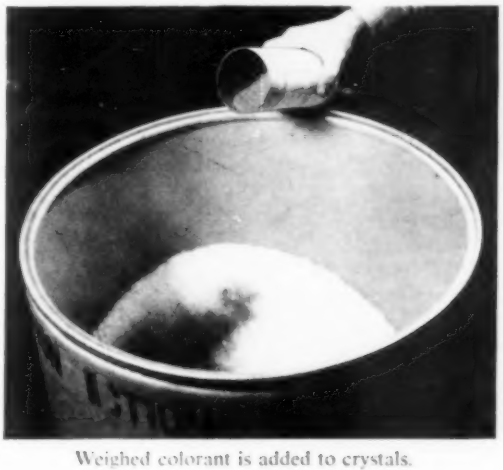
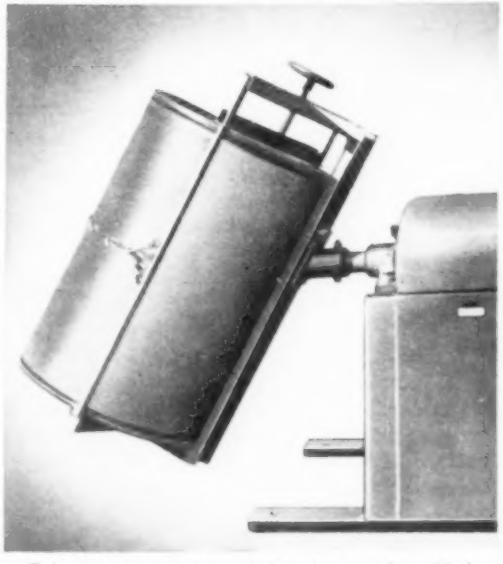
Lustrex Colorant Blend, supplied in handy 50-lb. bags, is poured into clean drum for tumbling.



Weighed colorant is added to crystals.



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First Prize Award—1952 Prize Paper Contes

The Basic Principles of the

C. E. Beyer and R. B. Dahl

The Dow Chemical Company

The controls available to the injection molding machine operator can be separated into two groups. Since the quality of the molding is primarily determined by the pressure in the mold and the temperature of the plastic at the time the gate freezes, the controls that directly affect this sealing pressure and temperature are classified as the primary controls. The other controls that either have no effect on the sealing pressure and temperature, or are predetermined by the primary controls, are classified as secondary controls. The effect of these controls on the sealing pressure and temperature is discussed. Some of the mechanical devices for producing the desired sealing point, such as weigh feeding and the ball check nozzle are also discussed.

C. E. Beyer

R. B. Dahl

IN THE PAST 20 YEARS shot size of injection molding machines has grown from a few ounces to the 300 and 400 ounce machines in use today, with even larger capacities being planned. Even with this tremendous growth in the size it has only been in the last few years that much work has been done on obtaining an understanding of the basic principles of the injection molding process. The operators of the giant molding machines now in use have the same controls as the operators of machines in the past. The molder of today knows that to produce a molding of the highest quality he must have the correct relationship between the:

1. Injection Temperature,
2. Injection Pressure,
3. Plunger Forward Time,
4. Mold Closed Time,
5. Mold Temperature,
6. Mold Open Time,
7. Clamping Force, and
8. Plunger Speed.

Most of these controls are so interrelated that a simp adjustment is not possible. For example, if the injecti temperature were increased the mold may start to flas so that the injection pressure may have to be reduced At this lower pressure the plastic may fill the mold slow so that the plunger forward time may have to increas This paper is an attempt to describe the relationship between the various controls available to the injecti molding machine operator.

These controls can be separated into two classifica tions, one a set of primary controls which directly contr the quality of the molding, and a set of secondary co trols which either do not directly affect the quality of th molding or are predetermined by the settings of the pr mary controls, as shown in Table I.

TABLE I

Primary Controls	Secondary Controls
Injection Temperature	Mold Closed Time
Injection Pressure	Mold Open Time
Plunger Forward Time	Clamping Force
Mold Temperature	Plunger Speed

A quick summary of the injection molding cycle is suf cient to show why each of these controls was classified a either primary or secondary.

The plastic is forced into the mold by the pressu of the injection ram at the temperature of the molte plastic, not necessarily that of the temperature controll settings. The pressure in the mold has been measured t be anywhere between 25 and 50% of the injection pre sure. After the material has completely filled the mol there is a short packing period where the injection ra holds the pressure in the mold as the plastic cools. Th rate of cooling depends upon the temperature differen between the plastic and the mold. The plunger then re turns to its starting position. If the material in the sma restriction at the entrance of the mold, commonly calle

Injection Molding Process . . .

the gate, has not cooled sufficiently to withstand the pressure in the mold there will be some discharge of plastic from the mold. This will lower the pressure in the mold to a pressure that the material in the gate can withstand. Thus the mold is now separated from the rest of the machine and the quality of the molding has now been established. The rest of the cycle consists of letting the plastic cool so that it may be removed from the mold. Thus the primary controls are those which determine the pressure and temperature at which the gate seals, and consequently, the quality of the molding. For the purpose of this discussion a good molding is defined as a molding free from sinks, bubbles, scoring, cracks, etc., which primarily depend upon having the correct amount of plastic in the mold. There are other defects that may appear in the moldings, and some of these are discussed from time to time.

DISCUSSION

The mold used to investigate the effects of the control variables on the mold pressure and plastic temperature was the same box mold described by Gilmore and Spencer. (1) The mold is a conventional type mold with a box shaped cavity. The size of the box is 4 x 4 in. square with a 2.500 in. draw. The gate dimensions are 0.035 x 0.375 in. with no land length. The wall thickness is 0.170 in. with a resultant shot size of 6 oz. in polystyrene. The pressure pickup was mounted in the cavity insert. The pressure measuring device works on the mutual inductance principle and is described in detail by Towsley (2). The cooling characteristics of this mold are known so that the average plastic temperature can be calculated at any time.

While the material is cooling in the mold the mold pressure, plastic temperature relationship can be determined from the equation of state of the material. For polystyrene the equation of state is

$$(P-\pi)\quad (V-\gamma) = RT \quad (1)$$

where P — Pressure in mold,
V — Specific Volume,
T — Temperature,
π, γ, & R are constants depending on the material.

For the constant volume situation that exists in the mold this equation when plotted with pressure and temperature as the coordinates as shown in Figure 1 would give a series of straight lines that would intersect at a temperature of absolute zero and a pressure $-\pi$ P.S.I. with the slope of the line depending on the density or the weight of plastic in the mold cavity.

As the plastic enters the mold the outer portion that touches the mold surface freezes almost instantaneously and as time goes on this layer increases in thickness until the whole molding is frozen. The gate is usually the smallest restriction in the system so that it will be the first place to freeze off. As the material cools the effective size of the gate keeps decreasing and the size of this orifice will depend upon the average plastic temperature. Thus, if the plastic temperature is lower the diameter of the molten plastic in the gate will be smaller thus holding a higher pressure in the mold. When this pressure, effective diameter and rate of cooling come to an equilibrium condition so that there is no flow through the gate the mold is then completely separated from the heating cylinder and the gate can be considered sealed. Below this sealing point the pressure and the plastic temperature will follow a line of constant density given by the equation of state for the material.

The sealing pressures can be determined experimentally from the pressure measurements and the point at which the cooling curve crosses this sealing pressure will give the sealing pressure and temperature required to

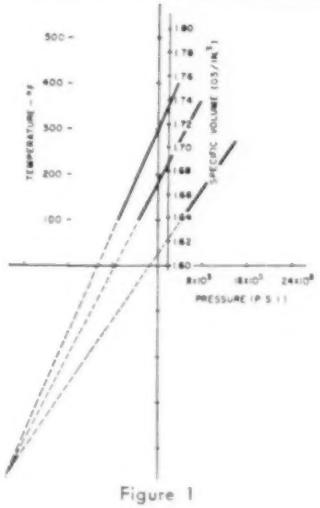

Figure 1

Pressure, Temperature, and Density Relations For Polystyrene.

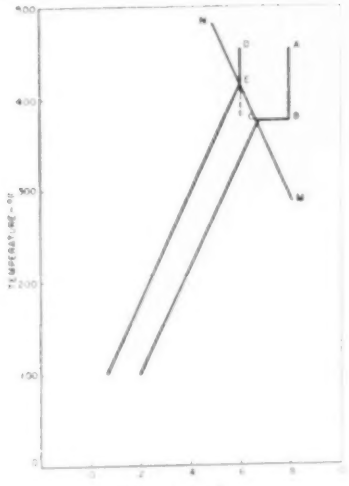

Figure 2

Pressure—Temperature Relations During the Injection Molding Cyle.

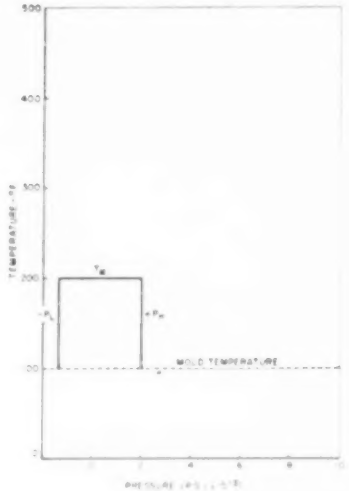

Figure 3

Mold Opening Conditions.

give that specific weight of molding. Several of these sealing points were determined by this method. For this mold these sealing points lay along line MN of Figure 2. In a complicated mold, particularly a very thin section molding, the pressure in the mold is not uniform, so that the experimental values of these sealing pressures will depend on the point at which pressure measurements are taken. This was then the sealing line for this particular mold below which the mold is completely isolated from the molding machine. The quality of the molded article is largely determined by the point where the pressure-temperature curve crosses this line. For example, if the sealing temperature was decreased the sealing pressure would be greater resulting in a heavier molding. The position of this sealing line will depend largely on the design of the particular mold and the size of the gate.

To explain the effects of the control variables on the molded article the mold pressure and plastic temperature at some point in the mold can be followed on a graph with the same coordinates as Figure I. The molten plastic is forced into the mold by the injection ram. After the mold has filled the pressure builds up to some value. This initial temperature and pressure is shown as Point A on Figure 2. During the packing portion of the cycle the plastic will cool while the injection ram keeps forcing material into the mold to maintain the mold pressure (Line AB). At Point B the injection ram releases the pressure and returns to its starting position. If the gate has not frozen there will be an almost instantaneous discharge from the mold dropping the pressure down to the sealing pressure, (Line BC). Once the gate has sealed the mold pressure and plastic temperature will fall off according to the equation of state. If the injection pressure were lowered (D), so that the gate sealed before the plunger returned, the pressure and temperature would follow the line given by equation (1) and the amount of plunger forward beyond this sealing point will have no effect on the weight of the piece. From this it can be seen that the weight of the molding is determined by the pressure and temperature at which the gate seals. Thus the major purpose of the primary controls and even such refinements as weigh feeding and the ball check nozzle is to give the correct mold pressure and plastic temperature at the time the gate seals.

SECONDARY CONTROLS

1. Mold Closed Time or Cooling Time

Gilmore [4] has found that to prevent sticking or scoring of the molding that the mold pressure must be close to zero when the mold opens. Of the molding has a core there will be a certain minimum value of the mold pressure to allow the molding to be removed from the core. The mold pressure range where the mold can open is shown + Ph — Pl in Figure 3. To prevent warpage or distortion of the molding there is a maximum plastic temperature at which the piece can be removed from the mold (Tm). This temperature will depend largely on the section thickness and the residual strains in the molding. The cooling time must be adjusted so that the mold will open when the plastic temperature and the mold pressure are within the boundaries + Ph, — Pl, Tm and the lower temperature limit which is the mold temperature below which the plastic cannot cool. The shortest cooling time is that when the pressure, temperature curve crosses one of these boundaries.

2. Mold Open Time

The mold open time is determined by the time taken to open the mold, remove the piece, and close the mold again. This is usually kept as short as possible but at times it may be held open longer to lengthen the cycle so that the plastic will remain in the heating cylinder longer to reach a more uniform temperature

3. Clamping Force

The clamping force required to prevent the mold from flashing depends upon the injection pressure and the cross-sectional surface area. It is usually set high enough to prevent the mold from parting under pressure and under these conditions has no effect on the quality of the molding.

4. Plunger Speed

The plunger speed or the rate at which the mold fills does have some effect on the sealing pressure and temperature since it determines how much the plastic cools before the mold is full. The rate of flow is determined by the injection pressure and temperature up to a maximum rate limited by the capacity of the hydraulic pump. In some cases, particularly in heavy section molding, it may be necessary to reduce the plunger speed to prevent burning of the plastic or other surface blemishes.

PRIMARY CONTROLS

Most of the plastics ordinarily used in the injection molding machines are very poor conductors of heat. The plastic will not remain in the heating chamber long enough to reach the temperature set on the controllers. Therefore, the plastic temperature as it leaves the nozzle not only depends on the heater settings but also on the rate that the plastic moves through the heating chamber. A method of measuring the plastic temperature and relating it to the heater settings and the output rate has been described [5].

The hydraulic system of the molding machine is set to deliver a predetermined hydraulic pressure to the injection ram. There is a large pressure drop through the granules in front of the ram which will vary with the amount of granular material ahead of the ram and the temperature of the cylinder wall around these granules [6]. There will also be pressure drops through all of the restrictions and channels between the ram and the mold. There will even be a pressure drop through the mold cavity itself. Thus for any given injection pressure the pressure in the mold at any point will depend upon:

1. The position of the ram at the end of its stroke,
2. The temperature of the rear of the heating chamber,
3. The temperature of the plastic, and
4. The pressure drop in the mold.

The primary function of both the injection temperature and pressure is to fill the mold with the required amount of material in a fluid state so as to prevent weld lines or surface marks. If the pressure built up in the mold is below the required pressure to make a good molding there will be excessive sinks or bubbles regardless of the plunger forward time. Therefore to make a good molding the pressure in the mold and the plastic temperature when the mold has filled must be greater than the sealing pressure and temperature required to give the proper weight of the molding. In all practical cases to fill the mold at a reasonable rate with the pressures available the plastic temperature must be much higher than the temperature at which the gate seals. While the plastic is cooling to the sealing temperature more material must be forced into the mold to compensate for the contraction of the plastic in cooling and maintain the pressure in the mold. This packing period can be shown as a vertical line extending below the filling point. (Figure 4). This packing period will extend until the plunger forward time

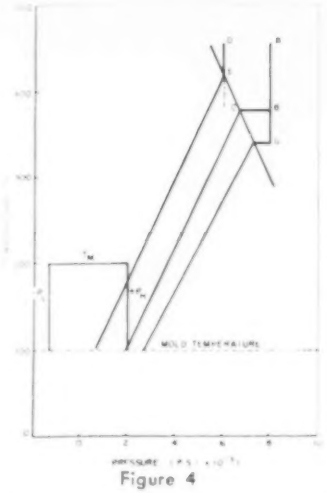

Figure 4

Effect of Injection Pressure and Plunger Forward on Weight of Molding.

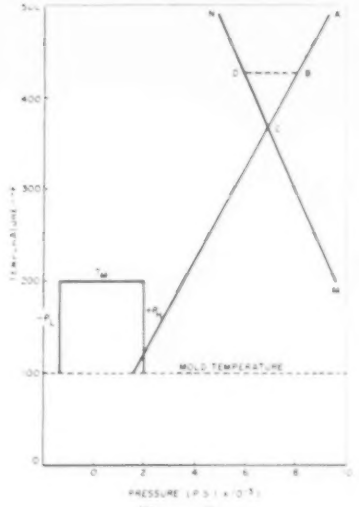

Figure 5
Pressure — Temperature Relations for Weigh Feeding

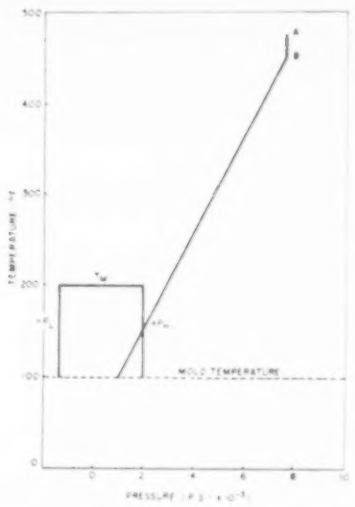

Figure 6
Pressure — Temperature Relations for the Ball Check Nozzle.

times out and returns the plunger (AB). Then the mold will discharge down to the pressure that the gate will hold in the mold at that temperature (BC). If the mold pressure at filling was low enough so that the gate seals before the plunger is returned any additional plunger forward time beyond the sealing point will have no effect on the molding (DE). On the other hand, if the gate does not seal, additional plunger forward time (BG) will cause the weight of the mold to increase. In this case the weight of the box is too large so that the cooling curve does not pass through the boundary limits (+Pr & Tm) for removing the piece and therefore the pressure in the mold is too high and scoring of the molding will result. The plunger time necessary to cool the plastic to the proper sealing temperature depends upon the rate of cooling of the plastic, and, since the rate of cooling is proportional to the temperature difference between the plastic and the mold, the plunger forward time is slightly dependent upon the mold temperature. The greatest effect of mold temperature is in determining the pressure and temperature of the plastic as the mold fills. If the mold temperature is too low, there will be too much cooling in the sprue and runners and also in the mold cavity itself, particularly in thinner section thicknesses, to produce a good surface on the molding.

WEIGH FEEDING

The purpose of weigh feeding and the various types of nozzle and gate valves is to maintain a closer control on the sealing pressure and temperature. In weigh feeding only the correct amount of material is placed in the mold. Because no excess material can enter the mold, the mold pressure cannot be above that required for a good molding at the time the gate seals. As long as the plunger forward time is sufficient to allow the gate to seal and prevent discharge, all of the moldings will have the same weight, producing a more uniform product. Another advantage is that the injection pressure can be much higher, giving faster filling without getting excessive mold pressure. In weigh feeding all of the material goes into the mold during the filling operation; there is no packing period where the plunger forces material into the mold to reduce the shrinkage due to cooling. (Figure 5). As soon as the mold is filled and the plunger reaches the end of its travel the mold is effectively sealed so that the pressure and temperature will follow the cooling curve given by the equation of state for that weight of material. (AC). As long as the plunger is held forward until the pressure and temperature cross the sealing line a good molding will result; but if the plunger forward time is too short, (AB), there will be some material discharged from the mold, giving a molding that is lighter than is necessary. This situation leads to more trouble than just one light molding. Since the one molding is light and the exact weight is being fed into the machine for each shot there will be too much material in the machine for the next shot which will then come out heavy. In practice this excess material does not come through in the very next molding but seems to build up in the machine and every so often a heavy molding is made that will probably be scored, or even stick in the mold. In molding by weigh feeding, it is necessary to have a long enough plunger forward to prevent discharge.

BALL CHECK NOZZLE

One type of nozzle valve used in injection molding is the ball check nozzle. The advantage of the ball check nozzle, as with all nozzle and gate valves, is similar to the advantage of weigh feeding. That is, to mechanically seal any desired pressure and temperature in the mold. Since in any molding operation the temperature of the plastic varies, and also the rate of cooling may vary, the gate will not always seal at the same point of its own accord. With a mechanical seal, the only variations will be the small variations in pressure drop through the heating chamber, causing only a small variation in the mold pressure. The ball check nozzle allows the plastic to flow into the mold but does not allow the material to discharge out of the mold. This is in effect sealing the mold when the plunger releases its pressure. As in weigh feeding the mold can be sealed at a higher pressure and temperature thus giving the advantage of higher injection pressure and the resultant faster filling of the mold. With the ball check nozzle there can be no sealing line and the sealing point can be anywhere along the line given by the equation of state for the correct weight to produce a good molding.

In Figure 6 the mold is filled at some pressure and

(Please turn to page 59)

Second Prize Award — 1952 Prize Paper Contest

A New Process for the Manufacture of Furfuryl Alcohol Resin Intermediates

Erik R. Nielsen

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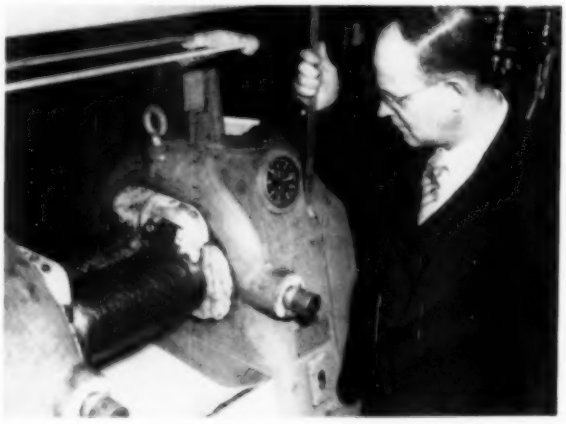
INTRODUCTION

FURFURYL ALCOHOL (hereafter designated FA) is prepared from furfural by hydrogenation. Soon after the advent of commercial furfural more than 25 years ago, the valuable properties of resins made from FA were recognized. Properly cured FA resins are highly resistant not only to alkali, but also to most acids and solvents. Notwithstanding these rather unique properties, the commercial acceptance and development of FA resins has been rather slow, and has been limited to coatings, cements, adhesives and impregnants.

The reason for the slow and limited acceptance of FA resins, notwithstanding the outstanding properties, must be sought in the difficult process considered necessary up to now for the preparation of such resins.

PRESENT MANUFACTURING METHODS FOR FA RESINS

At present, an intermediate liquid resin is first formed by refluxing the FA with an acidic agent or catalyst, in the presence of water or a solvent (the boiling water or solvent serves to remove the heat of reaction which is very great in case of the FA resinification, so great in fact that the reaction becomes uncontrollable, when catalyzed by an acidic substance, in the absence of a diluent). The refluxing is continued until a material of suitable viscosity (mobile liquid to viscous syrup) has been obtained. The waterinsoluble liquid intermediate is then neutralized and washed to inactivate and remove the acid catalyst, and is finally dried.



Erik R. Nielsen

Complete inactivation of the acid catalyst is necessary to obtain a stable intermediate, but this is possible only in case of intermediates of moderate viscosity. This in turn means that such intermediates are limited to applications such as coatings, casting resins, cements, adhesives, and impregnants.

To convert the neutral intermediate to the thermoset state, it must again be catalyzed with an acidic material and the catalyzed mixture has a rather short working life.

It has been attempted to produce intermediates sufficiently viscous to make them suitable for conversion into molding powders by the addition of a filler and a suitable catalyst. While such molding powders have actually been used, it is generally agreed that the shelf life is too short to make such molding powders practical. The short shelf life is probably due to residual active catalyst left in the viscous intermediate resin.

NEW FA RESIN INTERMEDIATE PROCESS

A stable intermediate resin of any viscosity could readily be obtained, if it were practical to produce such intermediates without an acidic catalyst, but this has not been practical up to the time of the process to be described here.

To be sure, it has been known that FA will resinify very slowly, if subjected by itself to prolonged heating at high temperature. Thus, Peters and Dunlop report (Industrial and Engineering Chemistry 34, 814-817) that less than 4 per cent is converted to a dimer when FA is heated 3 hours at 302°F, and less than 20 per cent when FA is heated 3 hours at 482°F. In other words, this method would be highly impractical for the manufacture of a FA resin intermediate, in case of which it is desired to go far beyond the dimer stage.

The above dimer percentage figures by Dunlop and Peters were based on the amount of water split out during the heating, in that the water formed showed the extent to which molecular dehydration or condensation had taken place.

The reaction for the formation of the dimer of FA is as follows:

$$2\,C_4H_3OCH_2OH \longrightarrow C_4H_3OCH_2C_4H_3OCH_2OH$$

It will be seen that the dimer still is an alcohol which can react in similar manner with a fresh molecule of FA to form a trimer. The latter again can react in similar manner with more FA, and so on. According to Dunlop and Peters (Alexander, Colloid Chemistry, volume VI (1946), Chapter on Furan Chemistry, page 1051), the above intramolecular dehydration or condensation plays

an important part in the resinification of FA, and this appears to be the accepted theory.

I have found that the above intramolecular dehydration or condensation may be made to take place not only quickly but also smoothly (in contradistinction to the violent acid-catalyzed intramolecular dehydration) by heating FA in the presence of a neutral catalyst, that is a special type of activated alumina (Patent applied for).

This finding was entirely unexpected, since non-acidic drying agents had been proposed for the purpose of minimizing the tendency of FA for intramolecular condensation or dehydration (Alexander, Colloid Chemistry, volume VI (1946), Chapter on Furan Resins, page 1058).

An example of the preparation of a FA resin intermediate according to my new process is as follows:

The resin pot shown in figure 1 is charged with 650 grams of technical FA and 63 grams of 8-14 mesh activated alumina composed substantially of gamma alumina, such as grade F-10, the Aluminum Company of America.

The FA is heated to boiling, with or without slow agitation. To start with, it appears that nothing happens, except that the FA vapors are condensed and returned to the resin pot via the trap. However, in about 20 minutes, the liquid collecting in the trap becomes cloudy, and shortly thereafter, 2 liquid layers form in the trap, the top layer being substantially water, and the bottom layer FA with a small amount of low molecular weight polymer, probably mostly dimer, which has been carried over with the FA.

The reason the above separation does not take place immediately is two-fold: one, some water must first be formed in the reaction taking place, and two, freshly distilled FA and water are miscible. However, as soon as some of the initial reaction product has been carried over, the water separates out (it is well known that it takes only a small amount of dimer in FA to make the mixture insoluble in water).

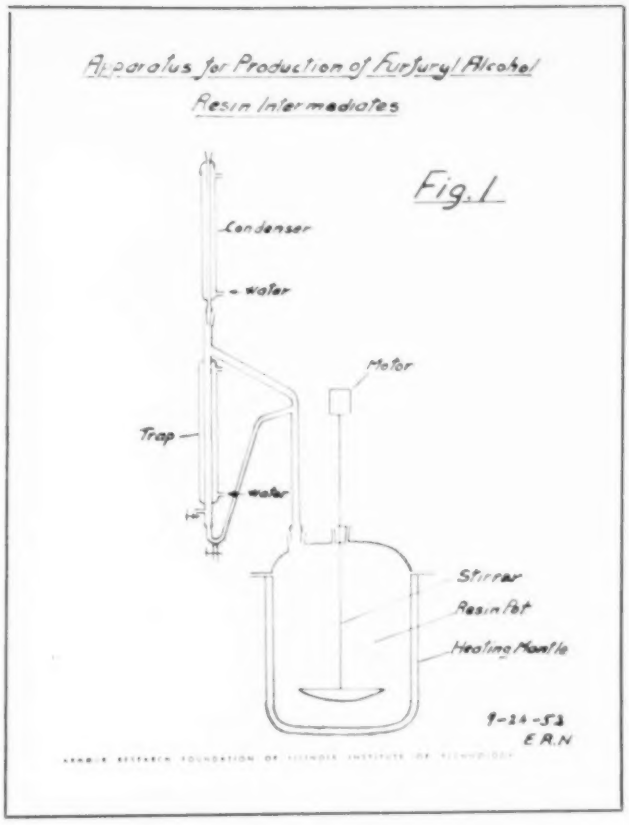
The water collecting in the trap is removed as needed through the valve on the side near the bottom of the trap, and at the end of the run, the FA collecting in the trap is removed through the bottom valve, instead of returning it to the resin pot, as done during the run.

The trap is cooled, since otherwise the hot condensed FA would cause the condensed water to boil intermittently, and with almost explosive violence.

One experiment of the above size (650 grams FA) was allowed to run for 1-¾ hours. At this point, the water split out in the reaction was 99 grams, and 61 grams unreacted FA was recovered in the trap. The slightly viscous hot resin intermediate was poured through a screen to remove the catalyst. When cold, the intermediate was a semi-solid. According to the Dunlop-Peters calculation method, cited above, the polymer formed had an average of 12 furan units to the chain.

While 10 per cent catalyst was used in the above experiment, it is perfectly feasible to use less catalyst. Thus, with 5 per cent of the above 8-14 mesh catalyst, the same result is obtained, but at a slower rate. However, the reaction is not speeded up significantly when more than 10 per cent of the same catalyst is used. When a coarser catalyst is used, the reaction rate is slowed down, but this may be compensated for by using more catalyst.

A fluid type catalyst, that is a very finely divided grade may also be used. In this case, as in case of the coarse catalyst, the reaction rate is slower than in case



of the above 8-14 mesh catalyst. However, also in this case, the reaction rate is speeded up, when more catalyst is used.

The use of a fluid catalyst is indicated when it is desired to use a mineral filler, since the catalyst may be left to serve as part of the filler.

The above variations between catalysts of different particle size are undoubtedly a reflection of differences in available surface area.

APPLICATIONS FOR FA RESIN INTERMEDIATES PREPARED ACCORDING TO THE NEW GAMMA ALUMINA PROCESS

An intermediate as the one described above, or one carried to a point of high viscosity, when hot, is suitable for conversion into a stable molding powder by the addition of a suitable filler and a catalyst.

One such molding powder was prepared by first mixing the resin intermediate (50 parts) with wood flour (40 parts) to produce an apparent dry powder, followed by blending in of maleic anhydride (10 parts) to serve as the catalyst. Test moldings have been made periodically with this molding powder over a period of 2-½ months, with no indication that the powder tended to pre-cure in storge (at room temperature over the summer). This test is being continued.

The better keeping quality of a molding powder of this type, as compared to one prepared from a conventional FA resin intermediate, is undoubtedly due to the fact that the new FA resin intermediate, prepared as it is without an acidic catalyst, allows for the preparation of a molding powder in which there is no intimate contact between the resin intermediate and the acidic catalyst added to effect the final cure. In case of the conventional FA resin molding powder, the resin intermediate always

(Please turn to page 58)

Third Prize Award—1952 Prize Paper Contest

Injection Molding of Elastomeric Vinyl Materials

Frank A. Martin
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INTRODUCTION

SINCE WORLD WAR II there has been a marked interest in the molding of elastomeric or plasticized vinyl chloride polymers and vinyl chloride co-polymer materials, for applications generally as replacements for rubber. This interest is not surprising since these vinyl elastomers have a number of properties which make them superior to rubber for a wide variety of products. It is not the purpose of this paper to discuss the properties of these materials in detail, but a brief description of the outstanding properties is in order. Since these compounds are thermoplastic and do not require a "curing" period, molding cycles require only a fraction of the time required for rubber "curing". Thus, they offer lower manufacturing costs. Also, since the molding is generally by the injection process in which the material enters a closed mold there is usually little or no flash trimming operation required, a further manufacturing economy.

Frank A. Martin working at a laboratory ribbon-blender.

The physical properties of the elastomers are in many ways superior to rubber. Polyvinyl chloride is inert to the deteriorating effects of oxygen, and thus does not suffer the same aging effects as rubber such as decrease in tensile strength and elongation with the attendant surface cracking. The vinyl compounds are in general more resistant to chemicals and solvents with certain exceptions. They can be plasticized to give much the same range of hardness as rubber, and a wide range of brilliant, stable colors is available. They can be molded with a high surface gloss finish not obtainable with rubber. The inherent toughness of the material makes this finish more resistant to scuffing and marring than a rubber compound of comparable hardness. The vinyl materials have good abrasion resistance, low water absorption, and are self-extinguishing. They are non-toxic, and may be compounded to be odorless and tasteless. By suitable selection of compounding ingredients excellent electrical properties may be obtained.

In contrast, the vinyl elastomers also have certain less desirable properties. One of the foremost of these is their temperature limitations. Because of their thermoplastic nature, the plasticized vinyls soften at elevated temperatures. A maximum operating temperature of 140°F. is usually recommended. However, some applications at temperatures of 170°F. have been made, and molded parts will not "unmold" at 200°F. although they become much softer. There are also low temperature limitations. With decreasing temperatures vinyls become progressively stiffer and less flexible, and they become brittle at temperatures higher than does rubber. Selection of suitable plasticizers will lower the brittle point, but no plasticizers are available which will allow PVC to compete with rubber for extreme low temperature applications.

Another possible limitation to the use of soft vinyls is the loss of plasticizer by volatilization, or migration of plasticizers into adjacent plastic or painted surfaces. By careful selection of plasticizers these objections may be considered negligible for the majority of applications. Since PVC is a saturated linear polymer incapable of the cross linking afforded by the sulfur vulcanization reaction of rubber, the vinyl compounds do not exhibit resilience and elasticity to the same degree as does rubber. They are, therefore, in general not suitable for dynamic applications where elasticity is a requisite factor.

While the vinyl resins are not soluble in the aliphatic hydrocarbons, care must be exercised in the compounding since the hydrocarbons may extract the plasticizers and stiffen the compound. Vinyls are inert to dilute acids, alkalis, and alcohols, but are soluble in ketones, chlorinated hydrocarbons, esters, and ethers.

The favorable properties of vinyl elastomers are being utilized in a multiplicity of molded applications. Many of these applications are the result of superior

color and finish. Others are the result of manufacturing economies, and still others take advantage of the abrasion resistance, toughness, and good aging. It is, therefore, natural that there is a growing interest in the injection molding of soft vinyls.

THE ECONOMICS OF MOLDED VINYLS

Elastomeric vinyl materials on a volume basis are considerably more expensive than the average grade of compound for molded rubber articles. However, injection molding cycles of 30 to 90 seconds are only a small fraction of the usual rubber curing cycles of 10 to 30 minutes. It has been shown that vinyl molded parts up to approximately 3 or 4 ounces in weight can be molded at a lower cost than a comparable rubber part. When a part weighs more than a quarter of a pound, the higher material cost of vinyls starts to overbalance the production economies, and the rubber part will generally be less costly to produce.

MOLDING METHODS AND ASSOCIATED PROBLEMS

Elastomeric vinyl plastic articles may be molded by any one of three methods; compression molding or injection molding of dry powders or granules, and slush molding of plastisols. Compression molding is of only limited application. Due to the thermoplastic nature of the materials the molds must be cooled while under pressure, with the result that molding cycles are very long and costs are high. Compression molding does have two advantages. Excellent surface finishes can be obtained readily and the exposure to heat is relatively brief so that the danger of heat degradation is small.

Slush molding of plastisols is outside the scope of this discussion, but it should be mentioned briefly. The process is economically sound and produces parts that are of excellent quality. Several companies have built automatic machines for slush molding. This process is becoming an ever increasingly important factor in the vinyl molding picture.

Naturally, the logical approach to molding these vinyl elastomers is by means of injection machines. The injection process is inherently a rapid one so that labor costs are low. By injecting the material into the closed die, there is no flash or overflow to trim. The rapid mold turnover permits large quantity production with relatively few cavities. However, the practical aspects of injection molding of soft vinyls are far from simple. Probably the primary cause of trouble in injection molding lies in the poor heat stability of the vinyl resins. This factor together with the low thermal conductivity of the vinyl compounds accounts for the molder's chief difficulty—**inability to achieve complete, uniform plasticization in the heating cylinder before thermal degradation sets in.** This non-uniform plasticization results in molded parts which may contain in the same piece overheated, underplasticized, and well-plasticized material. The properly plasticized material gives an excellent reproduction of the mold finish. Overheated material shows up as small teardrop patterns commonly referred to as "splash" marks. This condition is similar in appearance to the mica marks commonly obtained when molding damp cellulosics. Underplasticized material shows up as dull spots, pronounced flow lines, and weak welds.

It may, therefore, be concluded that the solution to doing a good injection molding job with soft vinyls lies in getting complete and uniform plasticization of the compound without subjecting the material to sufficient heat to cause thermal decomposition.

THERMAL STABILITY AND CONDUCTIVITY

Before considering methods of achieving this highly desirable degree of plasticization, it is first necessary to understand the problems imposed by the poor thermal stability and conductivity of the vinyl materials. Stabilizers such as lead, tin, and cadmium compounds are incorporated in all vinyl compounds, and they do improve the heat stability to a very marked degree. In spite of this improvement, there are no compounds yet available which will satisfactorily withstand the times and temperatures to which they may be exposed in an injection machine heating cylinder. Cylinder temperatures range from 330° to 380°F. or even higher, with 360°F. a commonly used temperature. Even though the torpedoes or spreaders in the cylinders have been streamlined as much as possible to eliminate obstructions where material may lodge and remain motionless for long periods of time, the streamlining is far from 100% effective. Therefore in spite of all precautions, it is impossible to keep some of the material from staying in the heating zone until thermal degradation sets in. The initial effect of exposure of PVC to excessive heating is change in color. The normal water-white resin passes through a pale straw color, to a reddish brown, to black on progressive heating. Once decomposition starts, the products of decomposition appear to accelerate the degradation reaction.

One of the end products is a carbonaceous mass. This forms first on the liner of the cylinder and acts as a thermal insulator. It then becomes necessary to increase the cylinder temperature to get enough heat through this carbonaceous barrier to plasticize the material in the inner layers. The higher heat encourages the formation of more carbon, which means that still higher heats are required to penetrate the barrier layer. There is no end to the decomposition cycle. When the decomposed material in the cylinder reaches a certain stage, it begins to break loose and come through into the product. At this point, it becomes necessary to dismantle the cylinder, clean out the burned material mechanically, and start over. It has been a common experience that cylinders can be run from one to two weeks on the average between cleanings.

The necessity of never allowing vinyl materials to overheat in an injection machine heater cannot be overemphasized. Precautions must be observed in starting a job to see that an occassional purging shot is taken as the material comes up to heat. Even more important is purging at the end of a shift or run. The heat should be shut off, and molding continued as long as the material will flow. Then the mold should be pulled from the nozzle, and further purging continued until the material temperature drops below 250°F. *(Please turn the page)*

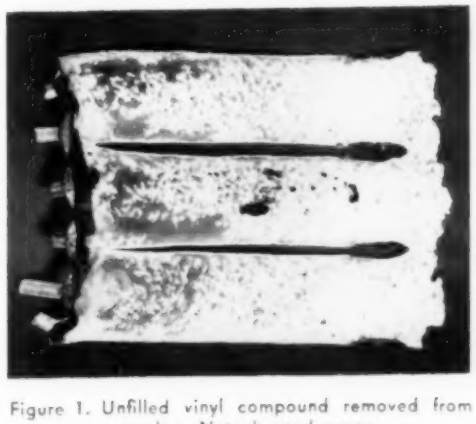


Figure 1. Unfilled vinyl compound removed from spreader. Note burned areas.

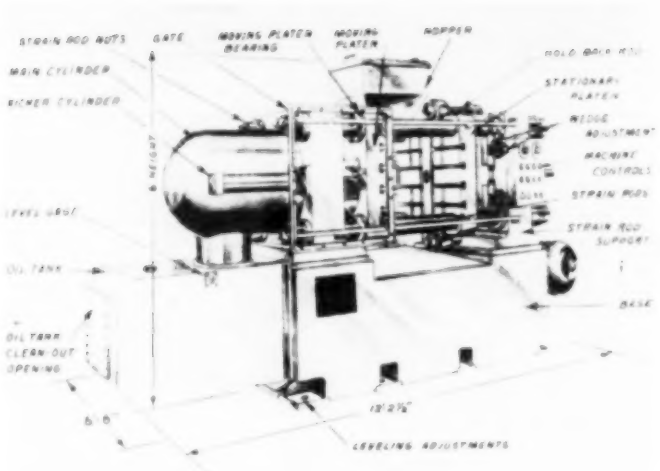


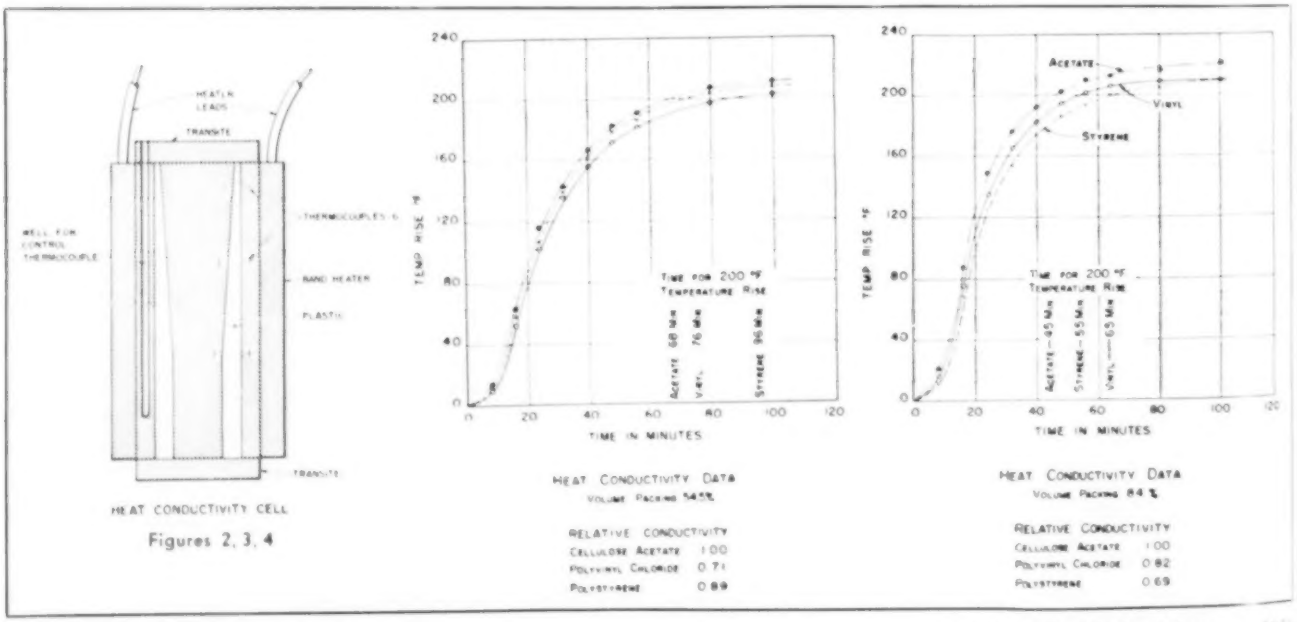
Figure 1 is a photograph of a 50 shore natural unfilled vinyl molding compound which was removed from an injection cylinder after burned material started to come through into the molded parts. Note the areas of burned material around the supporting fins of the spreader, and at the bottom where the material feeds into the nozzle. At these points the streamlined flow is obviously imperfect. In the center portion there are also burned areas. Many times the material is in a much further advanced state of decomposition when a cylinder is dismantled than is shown by this photograph.

Other products of thermal decomposition of polyvinyl chloride are hydrogen chloride and water. The hydrochloric acid so formed will attack chrome-plated cylinders. It may become necessary after extensive molding of vinyl compounds to refinish and replate the cylinders.

The problem of plasticizing vinyl elastomers by heat is aggravated by the poor thermal conductivity of these materials. Measurements were made of the relative thermal conductivities of typical vinyl, styrene, and cellulose acetate molding compounds in two different ways. In the one case the conductivity of a solid block 2 x 2 x 1 inch was measured. Realizing that the conductivity of solid mass would differ from that of loosely packed granules, a setup was made whereby the conductivity could be measured at various percentages of packing. Figure 2 illustrates a miniature replica of a heating cylinder. Thermocouples attached to a recording potentiometer served to measure the temperatures at six points simultaneously so that the progress of heat transfer through the material could be followed. With this equipment the effect of packing could be investigated.

Measurements of conductivity on the solid blocks rated the three materials in the following relative order: cellulose acetate—1.00, elastomeric vinyl—0.89, and polystyrene— 0.79. The conductivity as determined by means of the miniature heating cylinder is shown in Figure 3 for 54% packing and in Figure 4 for 84% packing. In each case the cellulose acetate exhibited the highest heat transfer rate. At 54% packing the PVC showed the lowest conductivity as evidenced by the fact that for the inner thermocouple to reach a temperature increase of 200°F. required 68 minutes for cellulose acetate, 76 minutes for polystyrene, and 96 minutes for the PVC. In other words, the PVC required 40% longer time to attain a temperature rise of 200°F. than did cellulose acetate. At 84% packing the cellulose acetate again showed the best thermal conductivity, reaching a 200°F. rise in 45 minutes, but the order of the polystyrene and PVC was reversed. The styrene required 65 minutes and the vinyl compound 55 minutes. These results rate the thermal conductivity in the same order as did the measurements on solid blocks.

Just which set of data is applicable to injection molding operations cannot be determined. Certainly the granules are loosely packed at the feed end of the cylinder, and just as certainly they have lost their identity at the nozzle end and are in a solid mass. There is undoubtedly a gradual increase in packing from the feed end to some point in the center where 100% packing is reached. In any event these experiments show that elastomeric PVC compounds are not, generally speaking, as good thermal conductors as are some of the other thermoplastic molding materials. Therefore, it is to be expected that the plasticizing rate will be slower. The combination of low heat conductivity and poor thermal stability thus



Figures 2, 3, 4

constitutes a formidable barrier in the process of injection molding.

The writer has seen discrete granules of material in the sections of the same shots which filled the mold cavities with apparently good parts. Certainly that indicates the difficulty of getting good plasticizing action. Increasing cylinder temperatures in these cases only resulted in burning before good plasticization was obtained.

SOME SOLUTIONS TO THE PROBLEM

There are two possible ways to attack the problem of getting better plasticizing action. One method is to improve the compounds. That implies increasing the heat stability of the resin or the thermal conductivity of the material. Other angles of attack on the compound may be to develop better flow characteristics either through the use of internal lubricants or by developing new resins with better temperature-viscosity characteristics. That field of endeavor must largely fall in the realm of the material manufacturers. It should be a highly rewarding field of research, since the development of a elastomeric vinyl compounds which can be molded without any of the troubles presently encountered should greatly stimulate the interest of molders and users in these materials.

From a molder's viewpoint, there are a number of things which can be done to obtain better plasticizing action. First of all, the machines may be used from a point beyond the heating cylinder to help plasticize the material. For example, frictional heat may be generated by forcing the material through a small nozzle opening. The use of nozzle opening of 0.080" to 0.100" in diameter materially assists in the plasticizing action. Nozzles down to .062" opening have been used experimentally with very good results insofar as plasticizing action is concerned. However, this opening was too small to pass the flakes of carbon which sooner or later appear, and frequent removal of the nozzle to unplug the hole was required.

Going on in the direction of material flow, further frictional plasticizing action may be obtained through the use of pin-point gates. The frictional heat generated as the material is forced through very small gates is sufficient in some cases to overheat the material and result in rejects due to splash marks. In such a case, opening the gate slightly will generally relieve this condition. On the other hand, when the gate cross section is too large, insufficient heat is generated to finish the plasticization, and dull or cold spots appear in the molded piece. Frequently the only alternative is then to weld the gate shut, and regate starting with a very small gate and gradually opening it until plasticizing action by means of frictional heat induced by pin-point gating is effective in producing good plasticization. It is difficult, however, to establish the optimum gate size, particularly when parts with large surface areas are being molded. In connection with the pin-point gate, the runners should be of the full round or trapezoidal shape, and of generous size.

The combination of poor thermal stability and low heat conductivity properties of vinyl elastomers makes it expedient to derate the injection molding machines to approximately 40 to 60 percent of the rated capacity. By designing molds to take substantially under the rated machine capacity the material takes longer to go through the heating cylinder so that in spite of its low thermal conductivity fairly good plasticizing action is obtained. Derating also by holding the material in the cylinder longer permits the use of somewhat lower temperatures in the cylinder, which are definitely beneficial in retarding thermal degradation.

Another common problem encountered in injection molding of plasticized vinyl materials is "back-rinding." This is a condition in which excessive shrinkage takes place at the gate and the part shrinks or pulls back into itself. This condition is not attributable to the plasticizing problem previously discussed, but is probably caused by the excess shrinkage of the hot material. There are several procedures which may cure "back-rinding." One is by proper control of the time the injection plunger is held forward. Another is by the use of relatively wide, flat gates. Neither method can be guaranteed for any particular job.

The estimation of material shrinkage for the purpose of establishing mold dimensions also imposes a problem. Shrinkage varies dependent on the amount and type of plasticizer used in the compound. In general, it will run from 1.5 to 2.5%. However, shrinkage of a given compound may also vary considerably when used in different molds. The only sure way to establish shrinkage is to make an experimental mold cavity and actually determine the shrinkage. Fortunately, the majority of applications for vinyl elastomers do not require very exacting control of finished dimensions, since these materials are used because they do possess the property of elasticity.

Still another problem in molding plasticized vinyls is one which is connected with that of plasticizing in the molding machine. There is a big difference in how easily the material may be heat plasticized between different shipments of the same compound. These differences mean that the molder must adjust his molding conditions to suit the particular lot being molded. Changes in temperatures and cycles are required in order to achieve satisfactory molding. Changes in molding cycles for a given job have been observed to run from 25 to 105%. While part of the blame for changing molding conditions may properly be attributed to changes in the plasticizing capacity of the cylinder due to carbonization, certainly there is a large variability in molding compounds from shipment to shipment.

PRE-PLASTICIZING—SCREW-TYPE MACHINE

There is another approach to the problem of plasticizing elastomeric vinyl compounds for injection molding. It is a matter of common knowledge that these materials can be thoroughly plasticized in a screw-type extruder. In that type of machine, the plasticizing action comes from two sources, externally applied heat, and frictional heat generated in the material by the mechanical working of the material. In fact, it is necessary in most cases when extruding vinyl elastomers to provide means of removing the excess frictional heat. The gloss and surface

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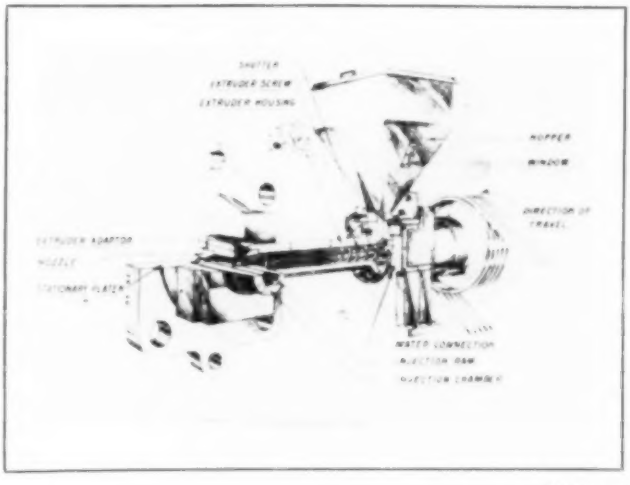


Honorable Mention — 1952 Prize Paper Contes

Compounding and Processing RIGID POLYVINYL CHLORIDE

Robert J. Ettinger
B. F. Goodrich Chemical Company

INTRODUCTION

THE DISCOVERIES made in the development of plastics during the past five years have brought about new material resources of great potential value. Plastics have been developed which are used for treating paper, wood, and glass as well as for thousands of manufactured articles, such as rainwear, upholstery sheeting, electrical insulation, drapery and packaging films, protective coatings, paints, and toys. These achievements of modern chemistry were largely due to the discovery and use of plasticizers. Plasticized polyvinyl chloride is well known for its versatility, for not only can the physical properties be varied with the type of polymer employed, but also with the quantity and type of plasticizer. Banburying, milling, extruding, calendering, and molding have been more rapidly accomplished when using plasticizers. Without plasticizers the wide range of physical and mechanical differences would not be obtainable.

Rigid PVC's are in the strict sense what the name implies; their properties are mainly those of the resin employed since stabilizers, fillers and lubricants are usually the only other ingredients. There are several differences between plasticized and rigid PVC. The most significant of these is hardness, which is directly related to high tensile strength, high flexural strength, and low elongation. Another difference is the high heat distortion point, which when compared to an average of 110°F. for plasticized vinyls is approximately 180°F. for rigid PVC. Also the addition of plasticizers lowers the chemical, electrical, heat and light resistant properties of the original polymer. Unlike plasticized vinyls, rigid PVC may be handled on woodworking equipment, and can be bent and welded by techniques similar to those used by the metals industry.

Although rigid PVC was known before plasticized vinyls, only within the past three years has it met with success in the United States. This was primarily due to the fact that unplasticized PVC materials were extremely brittle and difficult to process. This situation has been greatly relieved by producing a more workable resin through the use of various polymerization techniques. There are two common methods being practiced. First, manufacture a lower molecular weight resin from the monomer. Second, produce resins using vinyl chloride in combination with vinylidene chloride, vinyl acetate, maleates, vinyl benzoate, or acrylonitrile. Other alternatives are being used, namely, physical and mechanical mixing of a high molecular weight resin with small amounts of a low molecular weight resin. Any of these methods, of course, will lower the softening point of the resin and make processing easier. All of these methods are very useful but it should be emphasized that as one deviates from the straight vinyl chloride polymer to those of copolymers or terpolymers the entire range of physical properties will degrade. This is true particularly of such physical properties as the electrical, heat distortion, and chemical resistance.

THEORETICAL

WITH RIGID PVC as with many other plastics the physical characteristics and workability of the end products are of prime importance. The marked difference between PVC in the plasticized form and PVC used in rigid applications is the difference in plasticizer content. High molecular weight PVC is characterized by its hardness, toughness, poor workability and high chemical resistance. As this material is modified to improve workability and flexibility characteristics by either internal or external plasticization the unusual physical and chemical properties of straight PVC are modified to a considerable extent depending upon the degree of plasticization.

In general, PVC which contains, few, if any, chemical links between molecules, derives its characteristics from the strong internal molecular forces developed by dipole interaction. Where molecules are in close proximity and a high degree of dipole interaction can take place, as in unmodified PVC, the typical characteristics are in evidence. However, where bulky side chain groups of a neutral type are introduced into the molecule by copolymerization, the steric effect of these groups results in a physical separation of large segments of each molecule from those in the immediate vicinity and as a consequence, the softening temperature, hardness, and resistance to chemical attack are reduced.

The same effect is thought to occur when monomeric or polymeric plasticizers are intimately mixed with the

polymer becoming essentially a solution of plasticizer in the polymer where polymer molecules now are separated over long intervals by bulky plasticizer groups. This mixture again, because of reduced dipole interaction can be worked at relatively low temperatures and has relatively higher flexibility and relatively poorer chemical resistance than the original unmodified PVC.

In processing the rigid PVC, where little, if any, of the normally used processing aids are present, it is necessary to use considerably higher temperatures and more drastic processing conditions to fabricate this material than are normally used in vinyl plastics procedures. To overcome the extremely high molecule interaction by thermal means alone, results in a situation where processing temperatures for rigid vinyls approach the decomposition temperature of the polymer itself.

COMPOUNDING

As previously stated, rigid PVC requires compounding similar to flexible vinyls except that the main ingredients consist only of stabilizers, fillers, and lubricants. The basic physical and chemical properties of rigid PVC are determined to a great extent by the base resin, whereas, in flexible vinyls the plasticizer exerts the major influence. The aim of good compounding however, still is the development of a material with the desired physical, chemical and processing characteristics which relate to the end use requirement of the product. Not only is the selection of the compounding ingredients critical, but equally important is the means of incorporating them into the polymer necessary to develop the full properties of the compound. Since these factors are directly related to the base resin itself, the selection of an ingredient must be carefully chosen which will not detract to any appreciable extent from the physical properties of the original polymer. From a compounder's standpoint, the requirements to be considered in selecting the proper ingredients to formulate a satisfactory rigid PVC compound may be listed as follows:

a) **Processability:** The ingredient should disperse easily and process without difficulty.

b) **Effect on Physical and Chemical Properties:** The ingredient should not adversely effect the physical properties or the chemical resistance of the compound.

c) **Stability:** The ingredient should not readily effect the compound's resistance to thermal and ultraviolet degradation.

d) **Cost:** Low cost materials of good quality compatible with good compounding practices is essential.

e) **Heat Distortion Point:** The ingredient should be one which does not lower the heat distortion point below that of the original polymer.

f) **Compatibility:** Necessary materials which may be only partially compatible and may bloom or exude should be carefully chosen and used in suitable concentrations.

STABILIZERS

The inclusion of a chemical stabilizer to protect the rigid PVC from both heat and light degradation is of foremost importance. A suitable stabilizer is needed to counteract any decomposition which might occur due to the high heat histories which are usually encountered when processing rigid PVC. Not only must the stabilizer protect the life of the compound, but it must be compatible with the other ingredients so that full properties are maintained. The ideal stabilizer should be one which sufficiently stabilizes the entire compound, and have a specific gravity such that on a pound-volume cost basis, its use may be warranted.

Tin: This class of stabilizers offers excellent stability to the PVC compound. Though some tin stabilizers are effective in the prevention of both heat and light degradation, they are primarily known for their superior heat stability. Tin stabilizers have an advantage in that most of them can be used for either transparent or opaque compounds. Other classes of stabilizers may be used with tins if superior light stability is required, however, most combinations of tin compounds and lead should be avoided to prevent extreme discoloration of the compound. Tins have the disadvantage of being extremely volatile and cases of nausea have been known to occur among processing operators. Low concentrations of the order of 2-3% of the tins will satisfactorily stabilize rigid PVC. Rigid PVC may be stabilized with polymeric organic tin, organic tin, organic tin (mercaptide), dibutyl tin dilaurate, or dibutyl tin dimaleate. The latter two are efficient for both heat and light stability.

Barium, Cadmium, Epoxy: Both barium and cadmium stabilizers are well known, but a promising class of supplementary stabilizers is the epoxy type. In rigid PVC, a combination of these three in a 2:2:4 or 2:4:2 ratio respectively is desirable to produce both good heat and light stability. These ratios will vary depending upon the type of barium-cadmium-epoxy employed, but they usually follow one of the above patterns. This combined stabilizer system is used primarily for opaque compounds, however, transparents can be made if the given ratios are lowered by at least one-half. Of course, the stability of the compound will be poorer, but if medium temperatures and short fluxing cycles are used, adequate stabilization will take place. Some of the stabilizers which may be used in these combinations are, barium stearate, barium ricinoleate, barium laurate, cadmium ricinoleate cadmium laurate, cadmium-2-ethylhexoate, and several types of epoxys whose chemical names have not been revealed.

Lead: Lead compounds were the first to be used to stabilize plasticized vinyls, however, in rigid PVC they have not as yet assumed any great importance. This has been due to the high internal frictional heat involved in processing rigids, whereby breakdown of the carbonate groups or moisture from the phthalate, phosphite, and silicate groups is evolved in the form of gas, causing porosity. However, for normal operating conditions where prolonged periods at elevated temperatures are not encountered, there are several types of useful lead stabilizers when employed in 10% quantities; basic lead carbonate, dibasic lead phosphite, basic lead silicate, and dibasic lead phthalate.

Sodium: This class of stabilizers is known for its excellent light stability and should be used together with another class if both good heat and light stability are desired. Many of the sodium stabilizers pick up moisture and liberate this during processing causing porosity. With careful use of 2% or less sodium or sodium acid phosphates this difficulty might possibly be avoided.

Plasticizers

Although plasticizers are usually avoided in rigid compounds, it is sometimes necessary to use them to relieve some of the brittleness encountered with some PVC polymers. Monomeric or polymeric plasticizers which contain epoxy groups should be selected since they have very good heat stability. These should be used directly

with the representative stabilizer system when improving the flexibility and the stability of the compound.

FILLERS

Although fillers play an important part in aiding the processing operation of rigid PVC, they are used primarily as extenders rather than as aids to the physical properties. Through the choice of appropriate fillers the ease of processing can be increased depending upon their particle size, purity and dispersibility in the resin. Fillers do not usually have much bearing on the tensile of rigid PVC, but in many cases, exert some influence on impact, flexural strength and creep. Plastic compounds will not take as heavy a load of fillers as the rubbers, and in most cases, the upper limit as to the quantity employed usually does not exceed 20%. Above this point, the physical properties of the compound begin to decrease.

There are numerous fillers produced which have the same chemical composition. To distinguish between the useful ones there are considerations to be made other than the standard characteristics.

1. **Particle Size:** Indications are that as the particle size decreases, improved processing rates, smoothness and gloss are more apparent while dispersion becomes more difficult. However, dispersion of particle sizes below one micron is more easily accomplished with rigid PVC than in plasticized vinyls because of high shear encountered in processing the unplasticized material.
2. **Coatings:** There are numerous fillers produced which contain an organic coating on the particles. In many instances, these coatings aid processing and improve the surface and gloss of the compound, while in others they have a definite adverse effect. For example: Some compounds that contain coated fillers are not suitable for laminating because the lubricating effect of the coating prevents adhesion of the sheets.

Although fillers are used as extenders, and to improve mechanical properties of a compound, only a few types are useful in rigid compounds. **Calcium Carbonates:** This filler is primarily a very low cost material which can be used to improve the molding and surface of the end product. **Titanium Dioxide:** This material is effective as a reinforcing pigment, and also as a filler to improve extrusion, calendering, molding, and surface of the compound. In addition it reduces the brittleness or conversely improves the impact strength of the rigid PVC. **Iron Oxide:** This material also is known as a reinforcing pigment. When combined with the PVC resin, impact is improved, and high gloss upon extrusion and [illegible] is produced. Iron oxide is difficult to disperse, b[illegible] satisfactorily incorporation can be accomplished by le[illegible]ing the processing cycle.

LUBRICANTS

The addition of small amounts of lubricants ha[illegible] a remarkable effect on the flow properties of rigid PV[illegible]. Because of their nature they are used as processing [illegible]ds in calendering, extrusion, compression molding, and injection molding. In general, the lubricants which [illegible]vent adhesion of the plastic to metal surfaces are those [illegible]hich are not easily compatible with the PVC compound. With rigid PVC approximately 4% of one or a combination of lubricants is needed for extrusion and molding compounds; whereas while only 0.5% is required for cal[illegible]ndering, transparent, laminating, and welding rod compounds. The more common lubricants which are used with rigid PVC's are as follows:

Mineral Waxes: Paraffin Wax

Vegetable Waxes: Carnauba Wax

Synthetic Waxes: Amides, nitriles, and nitrogen derivatives of higher fatty acids, and esters of polyhydric alcohols.

Most waxes are used to improve the extrusion rate and gloss, but the compound upon aging may show some degree of exudation.

Synthetic Lubricants: Stearic acid, lead stearate, dibasic lead stearate, calicum stearate, and barium stearate.

This class of lubricants is used mainly for calendering, but has found good use in extrusion and molding compounds.

Plasticizers: A few of the secondary plasticizers have been found which exhibit some lubricating effect on the compound. Methyl "Cellosolve" acetyl ricinoleate, glyceryl tri (acetyl ricinoleate), polythylene glycol di-2-ethylhexoate, triglycol ester of a vegetable oil fatty acid, and dioctyl sebacate are the ones most commonly used.

COLOR

From a customers standpoint color is one of the most important components of plastic materials. Rigid PVC compounds may be made easily in a wide range of stable colors. This is possible because the dispersion of the coloring pigments in rigids is more complete due to the higher shear involved during processing. The addition of a colorant to any plastic compound should be handled with more care than the addition of any other raw material. Small fractions as little as 0.01%, of a color must

EFFECT OF LOADING ON PHYSICAL PROPERTIES

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Geon 404	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Lead Stab.	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Ca. St.	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Iron Oxide	10	20	40	—	—	—	—	—	—	—	—	—	—	—	—	—
Clay	—	—	—	10	20	40	—	—	—	—	—	—	—	—	—	—
Ca Co.	—	—	—	—	—	—	10	20	40	—	—	—	—	—	—	—
TiO_2	—	—	—	—	—	—	—	—	—	10	20	40	—	—	—	—
EPC Black	—	—	—	—	—	—	—	—	—	—	—	—	10	20	40	—
Tensile (psi) x10³	6.80	7.10	6.95	7.25	6.95	6.85	6.45	6.30	5.45	6.90	6.75	6.70	7.10	7.15	7.20	6.15
Flexure (psi) x10³	14.5	15.7	15.4	14.0	14.4	15.0	14.0	13.9	12.7	14.8	14.7	13.9	14.4	14.8	14.6	15.1
Izod (lbs./in)	0.77	0.64	0.58	0.39	0.32	0.30	0.41	0.52	0.61	0.59	0.63	0.60	0.41	0.51	0.46	0.52
Sag °F	180	182	185	185	188	195	180	185	190	180	185	188	190	195	200	170

be carefully considered before their addition to the compound.

To help dispersion and to prevent a raw dry color from "dusting" the use of a color masterbatch is a very successful method of adding colors. Such a masterbatch is made by mixing 30-70% parts of color pigments in a resinous type plasticizer and then grinding on a 3 roll mill or ball mill. This produces a paste like material. The addition of this mixture to a resin enables processors to produce a color compound which may be granulated as another type of masterbatch. Either of these techniques improves dispersion while decreasing the error in weighing out colors. Since less than 2% of color is generally needed for a compound, the small amount of plasticizer has little or no effect on its physical properties. If raw colors are employed, the use of non-dusting types is helpful in preventing excessive loss. Since colors increase moisture permeability and decrease electrical properties, the specific color used must be selected on the basis of its effect on the end use of the compound.

COMMONLY USED PIGMENTS IN RIGIDS

Titanium Dioxide
EPC Blacks
Phthalo Blue
Indanthrene Blue
Phthalo Green
Chrome Yellows
Molybdate Orange
Betaoxynapthoic Reds and Maroons
Lithol Rubines — Reds
Pigment Scarlets
Black, Yellow, Red Iron Oxides

When processing rigid PVC transparents and white opaque sheets a very slight yellow hue will appear. To eliminate this coloration, approximately 0.3% of a violet masterbatch is employed in the compound.

1. Calco Oil Methyl Violet IRS (oil soluble)
2. Methyl Violet and Phthalo Blue (oil dispersed)

While both of these materials are made into plasticizer-color, or plasticizer-resin-color masterbatches. Number 1 is used for transparents and Number 2 with white opaque compounds.

PROCESSING

The next step in the development of a good consumer product is the proper use of the various processing techniques. Rigid PVC is a dry, fine, white powder which must be "fluxed" on a mill or in a banbury so that blending and mixing occur readily. This fluxing serves two purposes; first, it softens the resin into a highly viscous material whereby mixing of the various ingredients is possible; second, it disperses the ingredients so that a homogeneous mixture of the compound occurs. This technique is adaptable to all types of PVC materials, but there are fundamental variables which must always be considered, namely, temperature, pressure, and time. These in turn are governed by the nature of the resin and the compounding ingredients.

The chief problem pertaining to processing is the control of cost. There are four considerations: types of equipment, equipment power consumption, labor, and time. These factors may be controlled by fluxing and mixing the PVC as quickly as possible without overworking the equipment, and with the least possible handling of the material. These achievements are only accomplished by selecting proper compounding ingredients and processing temperatures, without which, waste in all phases of operation will occur.

As previously indicated the type and amounts of ingredients will effect the rate at which the compound will process. The processing temperature of rigid PVC is very critical. If the stock is too hot, degradation will take place, and if it is too cold, proper mixing and dispersion will not occur. Equally important are the high heat histories encountered with rigids, because of the high shear experienced in processing. Plasticizers are usually not involved so there is bound to be a considerable amount of working friction. This is effected not only by the speed of the equipment, but also by the clearance of the mill rolls and Banbury rotors. One sees immediately that a number of variables are present, however, most of these may be controlled by maintaining the correct STOCK TEMPERATURE.

Mill Mixing:

Mill mixing of rigid PVC on the conventional rubber mill is entirely possible, but it is a relatively slow operation and requires an experienced mill hand. The first problems to be considered are those of good dispersion. The chief causes of poor dispersion are: short milling cycles, low stock temperatures, and improper addition of compounding ingredients. The last of these is the most difficult to correct. Although there is no exact method for adding the ingredients, they usually follow this pattern.

1) PVC resin plus stabilizer (premixed)
2) Plasticizers (if added)
3) Fillers
4) Lubricants
5) Color Pigments

The best methods usually start by completely fluxing the resin-stabilizer combination. Since rigid PVC is a dry powder, a tight mill is necessary to obtain any adhesive action to the mill rolls. Because this action does not occur immediately, much of the resin will fall through the rolls. This will happen 4-5 times, but the amount of resin "banding" to the mill rolls will steadily increase if a portion of the "Banded" material is repeatedly fed through the rolls. Full adhesive action will take place within 4-5 minutes. After banding the resin-stabilizer combination, the remaining ingredients should be added slowly and away from the mill guides. When some of the ingredients, particularly lubricants, are added too fast, the batch loosens from the mill rolls and falls to the pan below. When complete banding has taken place, the compound should be rolled and passed at least 5 times through a tight mill to insure thorough dispersion of all ingredients. The best conditions for milling high molecular weight PVC are as follows:

Front roll temperature—300-320° F. (50-60 lbs. steam)
Back roll temperature—neutral
Roll clearance—25 mils or less
Average milling time—15 minutes
Stock temperature—340-360° F.

The time involved will depend upon how difficult the ingredients are to disperse. In general, it will vary to longer cycles as the loading is increased and to short cycles for unloaded (transparent) stocks. If the compound is milled properly it will appear smooth both on and after it is removed from the rolls. It will be glossy with no discoloration. If the stock has been properly milled, it can be reprocessed 3 to 4 times without damage to the end-use product.

Although scrap rigid PVC may be reworked, it will need slightly higher processing temperatures than those necessary with the virgin polymer. These same processing conditions may also occur with prime materials

which have been either under or over worked. Therefore, so that the rigid PVC may be processed at the same conditions everyday, it is necessary to predetermine the proper time-temperature cycle for each compound. These various differences in processing conditions are not as apparent with flexible vinyl materials, however, with rigid PVC, the total time-temperature range is very narrow and must be properly controlled. Flexible scrap can be reprocessed by itself, or can be combined with small percentages of prime material. However, with rigid PVC sometimes only 10% of suitable scrap can be combined with prime material in order to make the use of higher processing temperatures unnecessary. But if the scrap was originally well stabilized and processed correctly, a greater percentage might be used in combination with the prime compound.

Banbury-Mill Mixing:

The Banbury is the most practicable and desirable piece of processing equipment for rigid PVC compounds. Not only is it capable of operating at controlled temperatures and pressures, but it is designed to hold powders with a minimum of leakage. With PVC the ingredients can be incorporated together at the beginning of the fluxing cycle, thus reducing the time of mixing. The compound is a crumbly mixture when it is "dumped" at the end of the cycle. This does not mean that dispersion has not occurred or that higher temperatures should be used. Rather, experience shows that when lump-masses occur, it is caused by too high temperatures. A crumbly product is preferred because it sheets readily on the mill whereas, large masses ride the mill and make processing difficult. With a low molecular weight PVC, however, a soft one-lump mass is obtained after Banburying, and this may be easily processed on the mill. Banburying processing conditions for rigid PVC's are as follows:

1. The initial temperature on the shell and rotors is 220-250°F. with a steam pressure of 15-35 psi. This is needed to help adhesion of the resin-compound to the metal parts, and usually increases as the compound lubrication is increased.
2. Air pressure on the ram is usually 60 psi or lower.
3. Slow speeds of 30-40 rpm are desirable to reduce the high frictional heat.
4. The fluxing cycle is short and will vary from 3-5 minutes. The "drop" temperature of the recording pyrometer should read 290-310°F. This is the temperature of the Banbury and not the stock temperature which will be some 55-75°F. higher.

After the Banbury fluxing cycle is completed, it is necessary to form a continuous sheet on the two roll mill. Even though the Banbury batch is crumbly, it will form a sheet almost immediately when placed upon the mill. The milling conditions usually are:

Front roll temperature—300-320°F. (50-60 lbs. steam)
Back roll temperature—270-290°F.
Roll clearance—40 mils or less
Average milling time—5 minutes after banding

The batch size should depend only upon the capacity of the mill which should not be overloaded or a smooth, glossy, well dispersed sheet will not occur.

Calendering:

When the milling has been finished, the plastic material is stripped cut, rolled, and made into a thin, flat continuous sheet by passing it through a calender. With rigid PVC the following may be observed.

1. **Temperature:**—of the rolls should be between 310-330°F. with a small rolling bank.
2. **Thickness:**—of rigid PVC sheeting can be easily obtained in sizes from 5-25 mils.
3. **Speed:**—of the material leaving the calender will vary from 25-35 yards per minute, which is slower than plasticized PVC.

The problems that occur are numerous and require experienced operation.

1. **Sticking**—Is caused by improper temperature control or incorrect ingredients.
2. **Scorching**—Occurs when the stock temperature, because of heat "build-up", is higher than optimum processing conditions.
3. **Tearing**—or wrinkling is caused by improper use of take off equipment or by the material being too cold.
4. **Incorrect gauge**—is caused by improper roll clearance of the calender.

Extrusion:

A wide variety of extrude profiles is accomplished easily with rigid PVC's. The compound is supplied to the extruder in one of three forms.

1. Granules.
2. Strip fed directly from the mill to the extruder.
3. Powder-mix.

The most common method uses granules which are uniform in size. This is preferred because granules can be compressed more easily to produce good extrusions with dimensional regularity. This compactness also reduces the possibility of entrapping air which causes porosity.

With extrusion equipment, the most important factors are temperature controls. Although many of the extruders in use today are controlled mainly by steam heat, the trend is now directed toward electric heating using band, strips or cartridge heaters. This latter type is preferred because more accurate control of temperatures can be accomplished. With rigid PVC, the following conditions are recommended:

Rear Barrel	—335-355°F.
Front Barrel	—320-350°F.
Head or Adapter	—310°F. to neutral
Die	—350-380°F.
Screw	—Neutral to lower than stock temperature.
Stock Temperature	—350-370°F.
Breaker Plate and Spider	—Should have large perforations.
Screens	—None or not finer than 20 mesh.
Die	—An extended long land die the length of which should be approximately 1.5 times the o.d. of the die shape. It should be case hardened steel with a high polished chrome finish.
Screw	—Shallow stainless steel, hardened, high polished screw, constant pitch, decreasing depth, and a compression ratio of 2-4 to 1.
Speed of Screw	—Granules—15-25 rpm. Powder-Mixes—10-15 rpm.

Rigid PVC's do not extrude as fast as plasticized vinyls; the average output on a 100 pound machine is 75 pounds per hour. By employing the proper compounding ingredients, the correct screw, and the optimum operating conditions, an increased output can be expected. There has been much said about both the single and twin screw

extruders as to which are more efficient. Actually, excellent results occur with either. However, there are some who feel that with the twin screw there is more "working" of the compound, and that this type is preferred when making extrusions from powder-mixes with rigid resins.

With many types of resin compounds, the material must be preheated before it is fed to the hopper of the extruder. This is necessary to eliminate moisture which if not controlled will produce rough surfaces, or imperfections as fine bubbles. With rigid PVC this does not readily occur due to its low affinity for moisture. However, there is still this possibility for porosity. Because of the high temperatures employed in extruding rigid PVC there may be breakdown or "gassing" of the ingredients. These gases try to escape, but because the material is highly viscous, they usually remain in the compound, forming bubbles. This gassing does not occur unless the compound has been allowed to remain in the head of the extruder for at least 15 minutes. If the material extrudes with an average output rate normally experienced with rigid PVC, it will not take place. Usually this gas formation is not HCl splitting off from the PVC molecule, but it is due to an ingredient, usually the stabilizer. Therefore, selection of the proper ingredients for extrusion is of prime importance. Proper die design with good streamlining and cooling are also necessary to prevent air bubbles. Much can be done to eliminate these bubbles by cooling the material slowly. The use of warm water prevents the outside of the extruded section from cooling sooner than the inside. If this precaution is not taken with lower molecular weight materials which have appreciable shrinkage, bubbles are likely to form.

MOLDING

Compression Molding:

Molding with rigid PVC is more difficult to accomplish than with plasticized vinyls. This is primarily due to the poorer flow characteristics of rigids. However, laminating and drawing can be performed using either milled or calendered sheets. Molded products are sometimes made from lower molecular weight granules and powders, but only with limited success. Materials which are deep drawn from a single sheet should be well lubricated, while laminated sheets require a minimum amount.

The simplest molding technique is to place the milled or calendered sheet in the desired mold, and preheat it @ 340-350°F. under a pressure of 100 psi or less. After the preheat cycle, full ram pressure from 1500-12,000 psi may be applied slowly to form the desired shape without rupture to the material. When this cycle is completed the mold is cooled with circulating cold water for approximately 7-10 minutes or until the mold temperature falls below 100°F. before the material is released.

When working with transparent stocks the shortest possible heating cycle should be used to avoid discoloration. Although the heating cycle should be short, temperatures of 360°F. or higher should be used. This relieves the brittleness caused by the residual stresses that occur in transparent rigid PVC.

Transfer Molding:

Large molded articles such as valve castings or pipe fittings can be made from granules or preferably from an extruded rod. In either case, the material is preheated in a transfer chamber at 350-360° F. for 8-10 minutes and then force the material by means of a hydraulic ram into a split-sectional hot mold. The mold is maintained for 1-2 minutes under pressure and is then cooled down to 100°F. before removing the material.

Injection Molding:

Injection molding rigid PVC compounds is extremely difficult although some success has been achieved with the lower molecular weight materials. The conventional injection molding machines in use today do not permit proper flow of the rigid PVC, because of its high viscosity. Within the past five years much has been done with the so-called "preplasticized" machine. In this method, the material is heated, worked, and softened by a mechanical screw similar to methods used in an extruder. From this preplasticized chamber the material is slowly fed to the injection molding chamber, and when it is fully charged, the injection ram forces the compound into the mold. The preplasticizer chamber permits the compound to reach temperature equilibrium which allows the material to attain its maximum flow properties. Though this type of equipment has some difficulties to overcome so that rigid PVC may be readily injection molded, it is certain that a machine of this type will be necessary to overcome the problems that now exist.

APPLICATIONS

Although rigid PVC is widely used in Germany, it has had only minor success here in this country. Rigid plastics in the United States have a connotation that they are "substitutes for metals". Though there is truth in that statement, it does not imply they are inferior, for in many respects they are actually superior and less costly than metals. More manufacturers and consumers are realizing that rigid PVC is a versatile product which is playing a more important part in our everyday lives. Although the applications of rigid PVC are too numerous to mention there are a few prominent ones which are in use today: Chemical and salt water resistant pipe and tanks, house shingling and flooring, battery and typewriter cases, business machine shells, furniture supports —legs and arms, primary electrical insulation, permanent wall finishes, and weather resistant materials suitable for use from the Polar to the Tropic Zones. Yet there are many fields of applications where rigid PVC has not been given any attention.

When the "substitutes for metals" attitude is overcome by educating the public to the uses and limitations of rigid materials, the PVC demand will be enormous, and no doubt someday it will enjoy the success plasticized vinyls are experiencing today.

LITERATURE CITED

Clark, F. G. "Color Problems in Vinyl Film and Sheeting," India Rubber World, Feb. 1951.

Parks, C. E. "Properties, Applications, and Processing of Rigids," SPE Journal, Feb. 1951.

Perloff, J. W. "The Application of Inert Filers in Vinyl Plastics," Rubber Age, Oct. 1951.

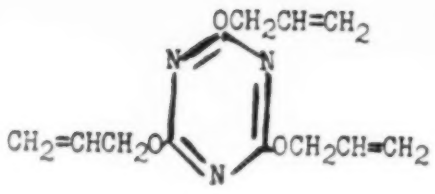
Platzer, Norbert "Unplasticized Polyvinyl Chloride," Modern Plastics, July 1951.

Ratti, H. J. "Vinyl Stabilizers," India Rubber World, Jan. 1951.

Simonds, H. R., Weith, A. J. and Schack, W. "Extrusion of Plastics, Rubber and Metals," Reinhold, 1952.

Vanderbilt Rubber Handbook, 1948 edition.

Zimmerman, H. M. and Weaver, P. J., "Compounding of Polyvinyl Chloride," Rubber Age, Dec. 1950.



TRIALLYL CYANURATE

H. M. Day and J. G. Affleck

American Cyanamid Company

ONE OF THE MOST interesting developments in the plastics field in recent months has been the preparation of resins which retain many of their room temperature physical properties when exposed to temperatures as high as 500° F. for prolonged periods. This development opens entirely new areas of plastics usage—structural applications in which competition with metals has not been possible in the past and fields where metals cannot be used for reasons involving light transmission, electrical properties, or heat conductivity.

The chemical which has made possible this increase in the scope of plastics application is triallyl cyanurate, a novel product which combines the functionality of three allylic groups with the triazine nucleus. This nucleus is one of the most thermally and chemically stable structures known to the organic chemist. Its combination with three polymerizable groups enables it to be incorporated into a wide variety of resins as a cross-linking agent. The extremely stable cross-links formed cause the resins to become resistant to alteration by the action of heat or chemicals. Advantage of these properties can be taken in the preparation of clear or filled castings or moldings, or, as discussed in this paper, glass fiber reinforced laminates. Various formulations have been prepared in order to obtain combinations of the following properties:

- High heat distortion point
- Good high temperature stability
- Low degree of change in electrical properties over a wide temperature range
- Fire resistance
- High degree of chemical and solvent resistance

Physical Properties of Triallyl Cyanurate

Table I summarizes some of the chemical and physical properties of triallyl cyanurate.

Table I

Molecular Weight (Theory)	249.26
Appearance at 30°C.	Colorless liquid
Melting or freezing point	27°C. (99.5% purity)
Boiling Point	162°C. at 2 mm. Hg
Density, g./cc. at 30°C.	1.1133
Viscosity at 30°C.	12.55 plus or minus 0.03 centipoises
Refractive Index at 25°C.	1.5049
Solubility	Completely miscible with such solvents as acetone, benzene, chloroform, dioxane, ethyl alcohol, styrene, and xylene. Very slightly soluble in water, 0.6 grams per 100 grams

Polymerization of Triallyl Cyanurate

Triallyl cyanurate, hereinafter referred to as TAC, readily polymerizes to give a clear hard polymer. The cast material has an ASTM heat distortion temperature higher than 200°C. An indication of the exotherm behavior can be seen from the following data which were obtained by placing a 10-gram catalyzed (2% Lupersol ATC) sample of TAC in a 18 x 150 mm. test tube, centering a thermocouple in the resin mass and recording the exotherm behavior after the assembly was placed in a constant temperature bath. (See S.P.I. method for determining exotherm behavior of polyester resins.) Exotherm behaviors were run at 100°C. and at 90°C. At 100°C. the polymerization was quite exothermic while at 90°C only a very mild exotherm was recorded even after heating for one hour.

	Bath Temp. 100°C.	Bath Temp. 90°C.
Time to Peak Exotherm	6' 30"	60'
Peak Exotherm	207°C.	107°C.

Glass cloth laminates made by saturating ECC 181-114 Fiberglas* cloth with TAC catalyzed with 1% Lupersol** ATC (equal parts of benzoyl peroxide and tricresyl phosphate) and pressed at 50 psi pressure between shims for 1 hour at 105°C. showed good strength properties at 500°F. confirming work done by U. S. Rubber Company. An indication of the heat strength properties and heat stability can be seen in Figure 1. These data show the excellent retention of the room temperature flexural strength at 500°F. and the thermal stability of TAC glass cloth laminates. The increase in flexural strength after 24 hours is undoubtedly the result of further curing of the resin.

Copolymerization of TAC with Reactive Alkyds

There are certain disadvantages to using TAC alone as a laminating material. First it is expensive since the synthesis utilizes a costly starting material. Secondly

*Owens-Corning Fiberglas Corporation, Newark, Ohio.

**Novadel-Agene Corporation, Lucidol Division, Buffalo, New York

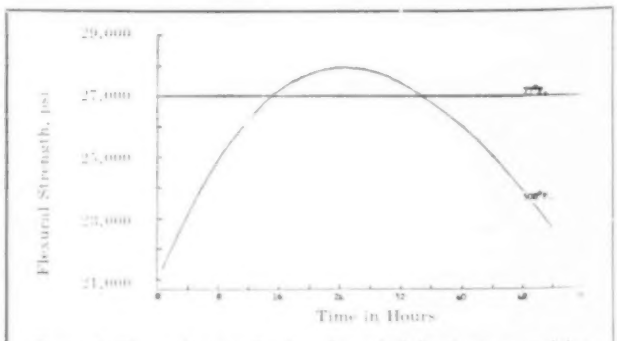


Figure 1. Flexural strength of a glass cloth laminate containing 38% polytriallylcyanurate

-Heat Resistant Resins . . . .

TAC has very low viscosity at laminating temperatures, making it difficult to obtain laminates having a proper resin content following normal laminating techniques.

TAC is readily compatible and copolymerizes with highly unsaturated polyester alkyds and this approach was taken in developing heat resistant formulations having good handling properties. Glass cloth laminates were prepared from resins containing varying ratios of TAC and a highly unsaturated alkyd resin and the flexural strength properties were measured at 500°F. after exposure to 500°F. for various periods of time. These laminates consisting of 11 plies of ECC 181-114 Fiberglas cloth were made by saturating the cloth with resin catalyzed with 1% Luperco ATC and pressing at 50 psi between shims for 1 hour at 105°C. Table II shows the variations in viscosity evaluated and the high temperature flexural strengths obtained.

The above data show that the TAC can be combined with unsaturated alkyd resins to give laminating resins of varying viscosity. Fiberglas cloth laminates made from these combinations show the same excellent flexural strengths at 500°F. and thermal stability as the all TAC glass cloth laminate. At this temperature the ratio of unsaturated alkyd to TAC does not appear to be critical, thus permitting a rather broad viscosity range suitable to many different types of applications.

As with the TAC laminates, the unsaturated alkyd-TAC laminates show increasing flexural strength on continued exposure to 500°F. heat. This is probably brought about by further curing of the resin and it may be necessary to post cure to obtain full strength values from laminates made with this type of resin. While it is recognized post curing will give increased flexural strengths, this was not carried out in preparing the laminates described in this paper. However, recommendations on this point are given in the following section.

Experimental Laminac® Resin PDL 7-669

Of the various blends tried, Experimental Laminac Resin PDL 7-669 appeared to have the best handling properties and was chosen for further evaluation.

This resin is described as a polyester laminating resin possessing unusually high strength properties at elevated temperatures. It is a non-volatile liquid having a viscosity of 65 poises at room temperature and can be cured with conventional polyester curing catalysts such as benzoyl peroxide or tertiary butyl hydroperoxide. Except for post cure, no special techniques are required in

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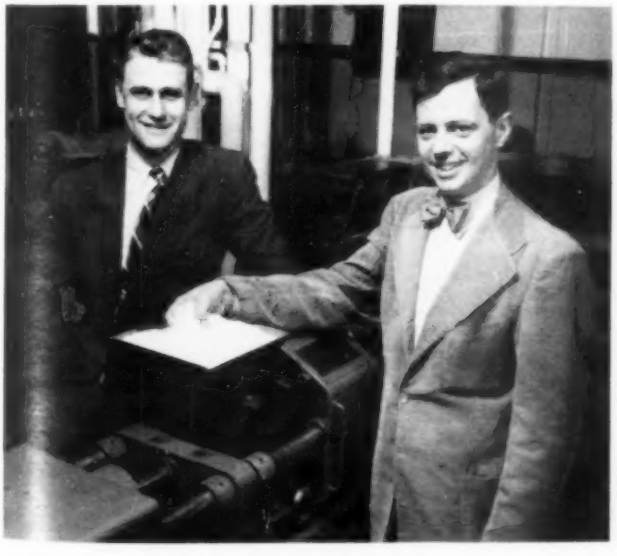


J. G. Affleck and H. M. Day

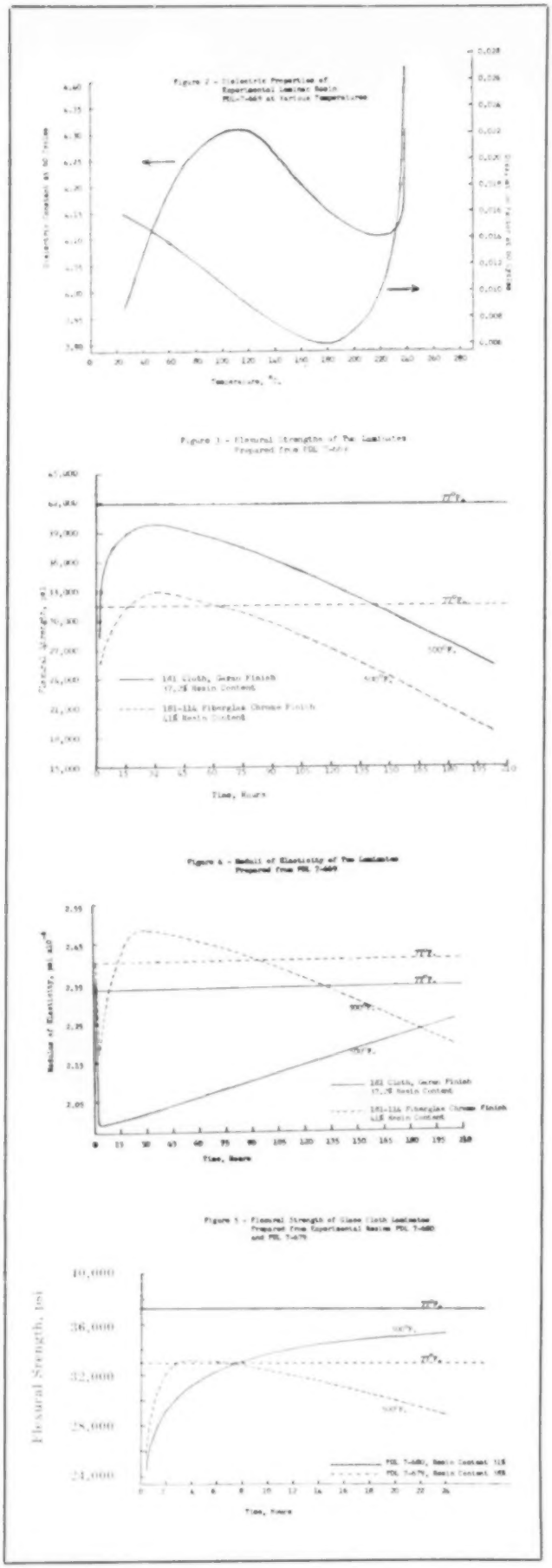
Table II

Resin	Resin Viscosity	Resin Content of Laminate, %	Flex. Str., psi at 500°F. After ½ hr. at 500°F.	Flex. Str., psi at 500°F. After 24 hrs. at 500°F.
100% TAC	0.12 poises	38	21,300	27,900
Laminac® Resin PDL 7-683	2-3 poises	36.2	21,700	32,300
Laminac® Resin PDL 7-669	65 poises	41	25,700	32,800
Laminac® Resin PDL 7-682	400 poises	37.7	20,400	27,400

Table III

Properties of Experimental Laminac Resin PDL 7-669

Resin Properties	
Appearance	clear straw
Viscosity	50-64 poises
Refractive Index	1.5112
Storage Stability	
Uncatalyzed at 25°C.	expected to be greater than 6 mos.
Uncatalyzed at 55°C.	greater than 5 days
Catalyzed 1% Luperco ATC at 25°C.	greater than 6 days
Catalyzed 1% Luperco ATC at 40°C.	18-24 hrs.
Catalyzed 1% Luperco ATC at 55°C.	12-18 hrs.
Physical Properties of Cured® Unfilled Resin	
Specific Gravity	1.346
Shrinkage during Cure (Density Change)	10.5%
Refractive Index at 25°C.	1.550
Heat Distortion, °C.	Approx. 270°C.
Barcol Hardness	60-70
Water Absorption 24 hrs at 25°C.	0.39
Flex. Str. at 25°C., psi	7,200
Flex. Str. at 80°C., psi	2,800
Flex. Modulus at 25°C., 10^6 psi	0.75
Flex. Modulus at 80°C., 10^6 psi	0.59
Armstrong®® Abrasion Resistance	0.193 mils. loss per 100 cycles (commercial melamine laminates 100 mils. loss)
Chemical Resistance of Cured Unfilled Resin	
0.5 N NaOH (24 hrs. at 25°C.) % Change Weight	−0.37
Conc. HCl (24 hrs. at 25°C.) % Change Weight	−0.60
Acetone (24 hrs. at 25°C.) % Change Weight	−0.23



using it. Cures can be effected at temperatures below 120°C. and at pressures as low as 50 psi.

There is much to be learned about this resin as it is still an experimental material. However, as a guide to possible applications, Table III lists the liquid resin and cured resin properties that have been obtained in the laboratory.

The dielectric properties shown in Figure 2 indicate a fairly uniform dielectric constant and dissipation factor over a wide temperature range. It is believed this is in part due to the high heat distortion point of Experimental Laminac Resin PDL 7-669.

Laminating with PDL 7-669

Most of the laminates prepared during this work were made following a definite procedure. The glass cloth is cut into the size desired, each of the layers of glass cloth are saturated with resin catalyzed with 1% Luperco ATC. Saturating the glass cloth is done by pooling resin in the middle of cloth and distributing evenly over the cloth. This process is repeated with each layer of cloth until the desired number of plies are obtained. In our work 11 plies of cloth were required to give the ¼" flat laminate used in our physical testing work. Following saturation of the cloth, the uncured laminate is placed between cellophane and pressed between ⅛" shims for ½ hr. at 105°C. and 50 psi. The cured laminate is hard, rigid and can easily be handled directly from the press. While a laminate made following this procedure has good strength properties, these strength properties can be greatly improved by post curing. A typical Fiberglas 181-114 glass cloth laminate as taken from the press showed a flexural strength at room temperature of 31,500 psi, post curing for 3 hours at 500°F. increased the flexural strength to 46,800 psi and in many applications it may be desirable and necessary to post cure.

Glass Cloth Laminates of PDL 7-669

For most of the laminating work covered in this report, ECC 181-114 Fiberglas cloth has been used. This procedure has been adopted for purposes of comparison and because this cloth appeared to be the best commercially produced for this type of usage. Laminates prepared with PDL 7-669 and the new vinyl silane sized cloths show particularly good strength properties (Figures 3 and 4). It is expected that other modifications of cloth finishes will result in even greater improvements in strength retention at elevated temperatures.

Figure 3 shows the flexural strengths of two laminates at 500°F. It should be noted that the shapes of the curves over the range of 24-200 hours are uncertain because of the lack of data pertaining to this interval. Experiments made at 300°F. indicate that no appreciable change in flexural strength or modulus of elasticity results after 200 hours at this temperature. This is true of PDL 7-669 laminates prepared from glass cloths having either the Garan or Chrome finish.

Experimental results not reported in Figures 3 and 4 indicate that 3-hour post cures at 500°F. result in greatly increased flexural strengths as shown in Table IV.

Table IV

The Effect on PDL 7-669 Laminates of 3-Hour Post Cures at 500°F.

Finish	Flexural Strength, psi		Moduli of Elasticity, psi x 10⁶	
	Not Post cured	Post cured	Not Post cured	Post cured
Garan	41,900	54,500	2.33	2.96
Chrome	31,500	44,500	2.40	2.85

*Resin catalyzed with 1% Luperco ATC—cure cycle 4 hrs. at 120°F. 9 hrs. to 250°F. and 2 hrs. at 250°F.

**ASTM Bulletin No. 143, 1946

Fiberglas Mat PDL 7-669 Laminate

Most of the work described in this paper deals with glass cloth laminates. However, in fabrication, particularly of complex shapes are made, it may not be possible to use glass cloth and it may be necessary to use glass mat or chopped glass fiber. Glass mat laminate using PDL 7-669 has shown the following flexural strengths when measured at 500°F.

Resin Content of Laminate	Flex. Str., psi at 25°C. (77°F.)	Flex. Str. psi at 500°F. after 3 hrs. at 500°F.	24 hrs. at 500°F.
67%	21,000	14,700	13,000

Improvement in the sizing of the mat similar to that done with cloth can be expected to increase these strength values.

Temperatures Higher than 500°F.

Most of the strength properties mentioned in this report are at 500°F. However, it is fairly certain that if the 500°F. requirements are met resins standing even higher temperatures will be needed. Anticipating this, some limited work has been carried out on Experimental Laminac Resin PDL 7-669 glass cloth laminates at higher temperature. Our present physical testing equipment is not suitable for flexural strength determinations at higher than 500°F. and it has not been possible to obtain comparable data. However, laminates have been exposed to temperatures of 550°F. and 600°F. for ½ hour and the resin loss determined.

	Resin Loss Calculated From Resin Content of Laminate After			
Resin Content of Laminate	½ hr. at 550°F.	4 hrs. at 550°F.	½ hr. at 600°F.	4 hrs. at 600°F.
41%	3.5%	24%	14%	62%

The above data indicate that Laminac Resin PDL 7-669 laminates will stand higher temperature than 500°F. for short periods of time. At 600°F. the loss in resin is quite rapid.

Heat and Fire Resistant Resin

Experimental Laminac PDL 7-669 while having excellent heat resistance is not fire resistant and in many applications fire resistance will undoubtedly be required. A limited amount of work has indicated that Laminac Resin PDL 7-669 can be modified as exemplified by Experimental Laminac Resin PDL 7-680 to give fire resistance without sacrifice of flexural strength properties at 500°F.

Experimental Laminac Resin PDL 7-680 may be described as a non-volatile white opaque liquid polyester resin having a viscosity of approximately 150 poises. This resin can be used in making glass cloth laminates having good strength properties at 500°F. The strength properties of the laminates can be greatly increased by post curing at 500°F.

The flexural strength data shown in Figure 5 were obtained on 11 plies Fiberglas 181-114 glass cloth laminate. As in the previous work 1% Luperco ATC catalyst and a cure cycle of 0.5 hours at 105°C. was used in making these laminates. The strength values shown are quite comparable to the previous values obtained on Fiberglas 181-114 non-fire resistant PDL 7-669 laminate.

Fire resistance is a misleading term unless defined. As generally used in the polyester field, fire resistance does not mean the plastic will not burn, rather it means the sample of plastic will be self-extinguishing after exposure to a flame for a definite period of time. In determining whether a resin is fire resistant or not, an Underwriters Laboratory Approval test was used. Briefly, a test sample 1" x 9" x 3/32" of a glass mat laminate of the resin being tested is suspended vertically so that one inch of the laminate is exposed in a 5 inch flame, one inch blue core, from a Bunsen burner. The sample is exposed for 30 seconds and then the flame is removed. To be fire resistant, the exposed laminate must be self-extinguishing in less than 20 seconds. Glass mat laminates made with Experimental Resin PDL 7-680 were self-extinguishing in less than two seconds even after the sample had been exposed to 500°F. for 24 hours. Glass cloth laminates under similar conditions were self-extinguishing within two seconds. For comparison, neither PDL 7-669 glass mat or glass cloth laminates are self-extinguishing.

Heat Resistant Resin for Dry Lay-Up

For some types of fabrication it may be advantageous to utilize a solid crystalline type resin which can be coated onto cloth or mat from a hot melt or suspension so as to give a relatively dry, easily handleable impregnated stock. For this purpose Experimental Laminac Resin PDL 7-679 has been formulated. This resin is very similar in formulation to PDL 7-669 previously described except it is a waxy crystalline solid instead of a liquid and has a melting point of approximately 185°F. (85°C.).

As a result of a limited amount of work with this resin, the following method of application is recommended for impregnation. A 50% solids suspension is made by agitation of the solid resin in an equal weight of acetone. This suspension is thixotropic, that is, it is almost solid when allowed to stand without agitation but becomes fairly liquid when stirred. One percent Luperco ATC is added and dissolved and the suspension is placed in an impregnation tank where cloth or mat is run through it. Squeeze rolls are utilized to control resin content at about 45%. An impregnation speed of 0.8 ft. min. was used in the laboratory equipment and the impregnated materials were run through an infrared drier to remove the acetone. Care must be taken to use the lowest temperature practical so as to prevent premature polymerization of the catalyzed resin. The dried impregnated cloth is practically tack-free and can be rolled between cellophane separator sheets and shipped. If in application a tacky impregnated sheet is wanted, Laminac PDL 7-669 may be combined with Experimental Laminac Resin PDL 7-679 in the impregnating solution; equal parts of each give a tacky sheet that may be desirable in some lay-up applications. Stability tests on impregnated material are not complete, but the material is expected to remain in a usable condition for a number of months if temperatures of 104°F. (40°C.) or above are avoided.

Laminates made from 12 plies of ECC 181-114 Fiberglas cloth impregnated with experimental Laminac Resin PDL-769 as above to 45% resin content, placed at 50 psi between shims and cured for one-half hour at 105°C showed final resin content of 38%. Laminate properties are given in figure 5.

Proposed Uses

Applications for these resins will undoubtedly suggest themselves very much more greatly to the fabricators than they do to the more isolated resin manufacturers. Doubtless many uses can be developed which will take advantage of their resistance to heat distortion and fire and mechanical resistance, and the stability of their physical and electrical properties over an unusually wide temperature range. Triallylcyanurate is a reactive monomer and can, therefore, readily be copolymerized with other unsaturated monomers.

It is anticipated that a variety of heat resistant resins will be prepared in this fashion in order to extend further the scope of plastics applications.

Electrostatic

H. A. Endres and W. T. Van Orman
Goodyear Tire and Rubber Company

Presented at the 9th SPE Conference

SYNOPSIS

The electrostatic properties of rubber and plastics have been always considered a nuisance factor to the manufacturer and consumer. In many cases electrostatic charges on plastic or rubber have caused fires in industry, the obnoxious collection of dust on plastic articles, and even deaths in hospitals.

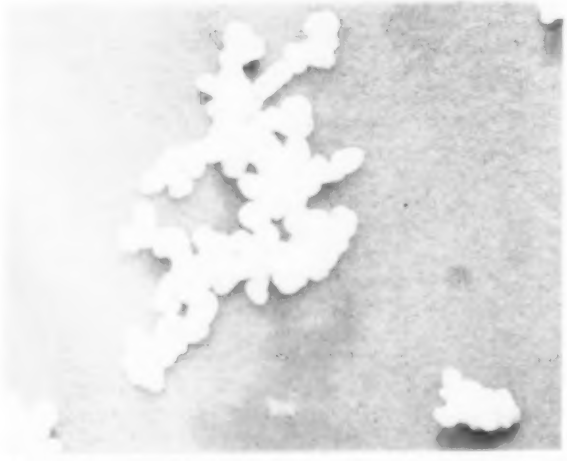
When incorporated in suitable form in air filters, the effectiveness of these electrostatic charges on certain plastics has been established in the laboratory, in engine air intakes, in dust allergy cases, in heating, ventilating, and air conditioning systems.

This paper is a study of static charges in plastics, and the authors have turned a nuisance factor into a new and desirable commercial use.

INTRODUCTION

IT IS THE PURPOSE of this paper to review the phenomenon of accumulation of electrostatic charges in rubber and plastics, the hazards accompanying uncontrolled electrostatic discharge, means of controlling or dissipating the charges, and to describe a useful application of this property of certain plastics.

Everyone has experienced the shock resulting from touching a grounded metal object after he has accumulated an electrostatic charge by walking on a rubber or plastic floor covering. The development of an electrostatic charge in this manner recalls the classic experiment in physics of rubbing an ebonite rod with a piece of silk or cat's fur and then picking up bits of paper by electrostatic attraction. In these instances the charge developed is of relatively low magnitude, and while it may be sufficient to produce a spark, it is harmless except under very unusual circumstances. However, when an electric charge is developed in an industrial process the conditions are usually such that more and more charge will accumulate until it exceeds the insulating ability of the surrounding air and then escapes as a spark of sufficient magnitude to constitute a definite fire hazard or source of mechanical trouble. If such sparks are produced in areas containing flammable gas or dust, serious fires or explosions may result.



Electron micrograph of smoke particles used in air filter tests. The carbon spheres are 0.05 microns in diameter.

A spectacular result of a natural self-charging mechanism is seen in lightning. Vertical currents, rushing through water droplets, break them up and create electrical charges in the surrounding air. From these tiny charges, lightning discharges of 6 miles in length may be generated. Voltages as high as 100,000 per foot may be encountered and currents up to 200,000 amperes have been measured according to A. O. Austin (1a). Electrical charges generated on aircraft are quite small and insignificant compared to lightning. Therefore, the covering of aircraft, such as metal or fabric, does not have a too important role as a generator or non-generator of electrostatic charges, but rather sufficient metallic conductor should be provided to conduct lightning harmlessly through the aircraft. Conductive or metallized balloon fabric does not afford adequate conductive capacity, hence a metallic conductor is indicated for lightning discharge. A splendid example of a negative discharge is well illustrated in the photo showing lightning striking the Empire State Building in New York City.

DEVELOPMENT OF ELECTROSTATIC CHARGES IN RUBBER AND PLASTICS: HAZARDS AND CONTROLS

Silsbee (1) presents an interesting table of crest values for triboelectric sparking voltages and reaches the

Properties of Rubber and Plastics . . .

confusion that a potential of about 28,000 is required to produce a spark one inch long between needle points. Measurements made with an electrostatic voltmeter on plystock coming from a calender have shown potentials as high as 50,000 volts, which would be sufficient to produce a spark more than two inches in length. In all the processes of the rubber industry where textile fabrics are being coated either by spreading or by calendering, or where the rubber coated stock passes over rolls, electrostatic charges are developed. As a result of its extremely high resistivity, the rubber coating, when once charged, will retain its electrification for a period of time determined by the prevailing conditions. Also because of its high resistivity, the rubber cannot be de-electrified by simple contact with a ground. Ionization of the ambient atmosphere relatively close to the stock is perhaps the most effective way of removing the charge. This can be done by means of electrically operated static eliminators, or by radiation emitted from radioactive materials such as polonium, which will be discussed later.

Before the introduction of these more recent methods of static elimination it was common practice to remove the charges by proper grounding of the equipment, materials, and personnel. Such devices as contacting the charged material with metallic tinsel cord connected to a ground, or passing the material close to a row of closely spaced sharp metal points projecting from a grounded metal rod have been employed. Moving equipment and personnel can be grounded by means of conductive floors containing metal inserts, or by conductive rubber floor coverings.

The principle of electrically operated static eliminators, according to Pennell (3), is to provide a localized alternating ionized field through which the charged material passes, instantly and completely losing its static charge by neutralization and thus restoring the electrical balance. This is called "neutralization by ionization".

Another method of preventing the accumulation of electrostatic charges that is widely used is by humidification. Most insulating materials have the property of absorbing a thin layer of moisture which usually contains enough dissolved material to render it slightly conducting. Some waxes and plastics do not develop surface conductance in the presence of water vapor and cannot be discharged in this manner.

For humidification to be effective, the relative humidity should be at least 50%, and preferably 60% or more. In many industrial operations such humidities are deleterious to the stock, as in the case of calendered plystock. On the other hand, humidities of 20-25% have been found to accentuate the electrification of the stock during processing. In a paper on fire hazards and static electricity in rubber factories, Hoxie (2) points out that the fire hazard is greatest at the time of least humidity and three-fourths of the fires are caused by a deficiency in atmospheric humidity. An interesting sidelight reported by Turkington (4) is the variation in the hazard from individual operators, some of whom are "human dynamos" because of skin dryness. In one instance, five shoe machine fires from rubber cement were attributed to one operator, and the difficulty was corrected by changing operators.

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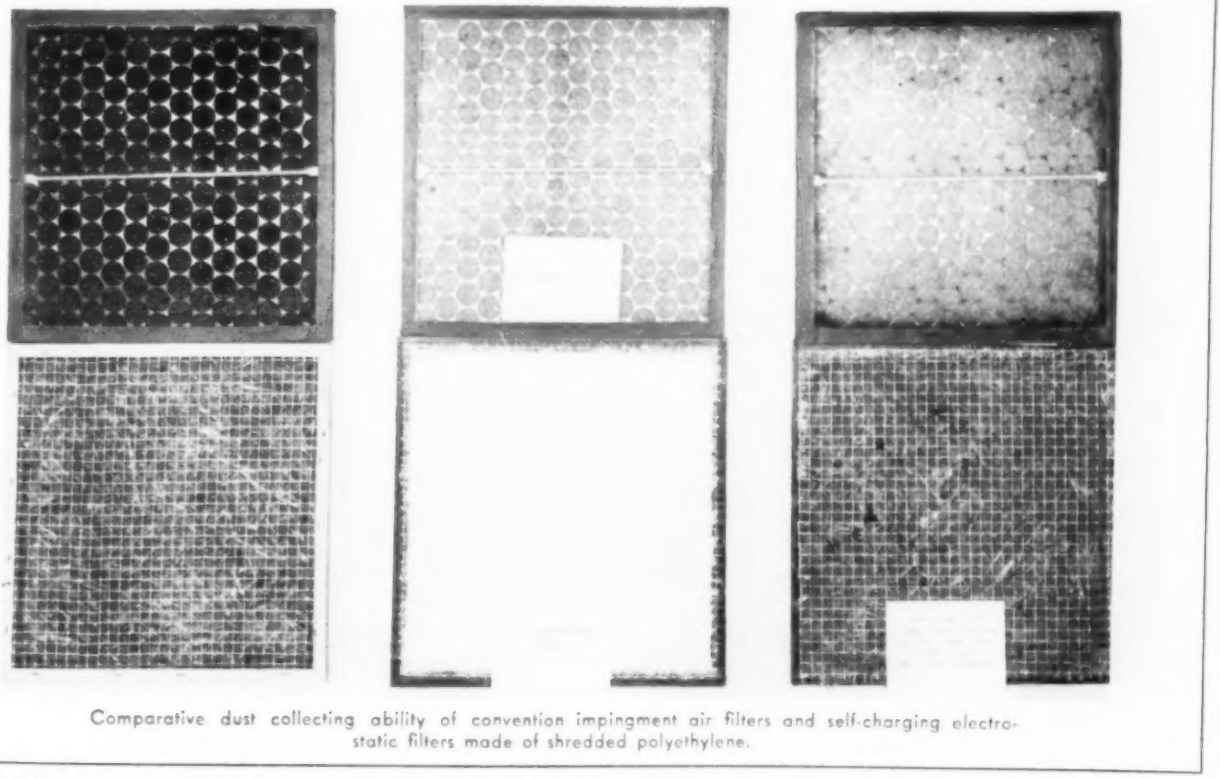
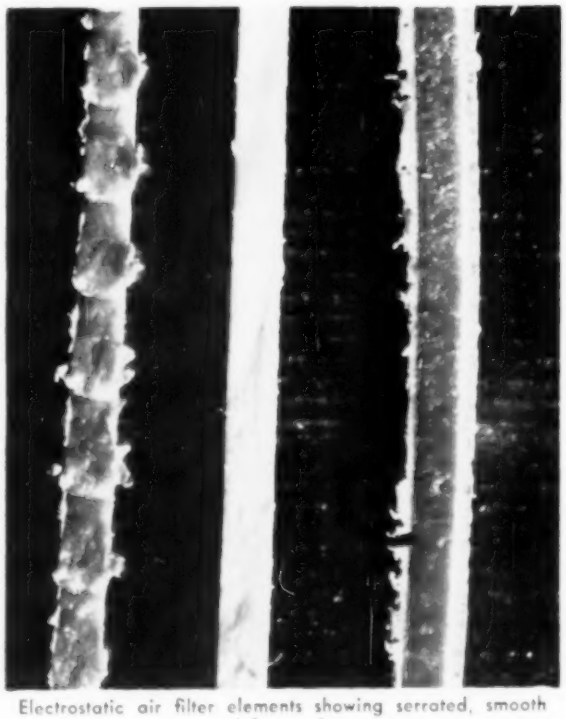


Comparative dust collecting ability of convention impingment air filters and self-charging electrostatic filters made of shredded polyethylene.

There are numerous references in the literature to fires and explosions in the rubber, [14] [15] [16] [19] petroleum, [17] [18] cereal, powdered metals and other industries caused by electrostatic sparks. The accumulation of inflamable dust in the air carrying static electrical charges has been shown by Beyersdorfer [5] to be a direct cause of dust explosions. In the autumn of 1948 the newspapers reported several anesthetic-gas explosions in hospitals in the eastern section of the United States. It is generally conceded today that sparks from static electricity are the most common cause of fires or explosions of combustible anesthetic gases and vapors. This is one of the factors against the use of ether as a general anesthetic. Electrostatic charges may develop in the rubber tires of operating tables and operating room carriages when they are moved over the floor, or on personnel by walking and scuffing on rubber floor coverings. Pulling a sheet over a rubber covered mattress may develop an electrical charge, especially if the sheet is made of a high dielectric plastic material, or most of the usual synthetic fabrics. To insure complete removal of the hazards of static electricity in hospital operating rooms the U. S. Bureau of Mines [6] recommends that all rubber goods used be of the conductive type and that the use of articles made of plastics or synthetic fibers be prohibited.

The generation of static electrical charges on transmission and conveyor belts has been analyzed by Silsbee [4] and others [7] and means of dissipating the charges are discussed. Most motorists have experienced the electrical shock resulting from the static charges developed in automobile tires. This has been studied rather extensively by Beach [8] and others, [9], [10], [11], [12], [13], who found that the dielectric properties of the compounding ingredients used in the rubber and the nature of the tread design are important factors. Potentials of 6000 volts may be produced at speeds up to 35 m.p.h. [10]. It is interesting to note in this connection that Butyl rubber inner tubes containing carbon black have relatively high electrical conductivity, which results in lower accumulation of static charge on vehicles thus equipped. [20]



Electrostatic air filter elements showing serrated, smooth and fuzzy edges.

The effect of the activated oxygen and ozone on rubber, due to electrostatic discharge in the air, has been studied by several investigators. Cotton [21] proposed the idea that ionization of oxygen both on the surface and through-out the mass of rubber on a masticating mill, caused by static charges produced by friction, plays some part in promoting oxidation. This was confirmed by Busse, [22] who concluded that the rate of oxidation is increased by the activation of oxygen during milling owing to the electrical charge which develops, resulting in the formation of a rubber peroxide. The electrostatic charges built up by the movement of an inner tube in a tire casing are discharged at the contact surface of the tube and casing. Such a discharge could cause surface crazing of inner tubes, since traces of ozone might be formed, according to Sperberg [20] and co-workers.

ELECTROSTATIC DUST COLLECTION ON PLASTICS

Static electricity has long been a nuisance in the manufacture and use of plastics. The annoyance caused by particles of plastics adhering to grinding and shredding machinery is well known to processors. In packaging operations where thin films of plastics are employed, production may be greatly curtailed by static charges developed during printing and at the bag and packaging machines. Perhaps the greatest nuisance is the collecting of dust on plastics during use due to electrostatic deposition. In 1933 a colorful display of plastics at the World's Fair in Chicago had to be removed because of excessive dust collection. This was probably the first graphic demonstration of this phenomenon. Since then there have been numerous examples of a similar nature. During World War II the accumulation of dust on aircraft instrument dials and canopies made of plastics caused considerable trouble. Showroom and advertising displays of plastics are frequently covered with dust. Wiping the dust off with a dry cloth simply serves to create an additional electrostatic charge and increases the dust collecting ability of the article. One manufacturer of lighting fixtures recommends cleaning with a cloth saturated with trisodium phosphate solution. The film of salt thus left on the surface absorbs sufficient moisture from the air to give a thin conducting layer and reduces electrostatic dust attraction. Music lovers are familiar with the crackle and pop resulting from dust covered plastic phonograph records and the electrostatic devices that are available for removing the dust. A very thorough investigation of the mechanism of electrostatic dust collection on polystyrene wall tile has been made by Woodland and Ziegler. [23] By blending red and green fluorescent pigments of opposite polarity and allowing these to collect on polystrene wall tile by electrostatic attraction, these investigators obtained striking "black light" colored photographs which showed the presence of positive and negative charges side by side in finely divided patterns. They found that areas having static charges of a relatively mild nature are almost sure to collect dust in some form, whereas very strong positive and negative charges existing in close proximity are sure to have unusual and well patterned dust deposits. Using a similar technique Hull [24] showed how electrostatic charges are distributed on materials such as paper. Paper from heat-set printing presses showed streaks of static electricity generated by idling rollers and shifting patterns generated at the folder, often with opposite charges

on the same sheet. The polarity of the electrostatic charges on raw rubber, gutta-percha, soft vulcanized rubber and ebonite has been studied by Shaw [25] and by Deodhar [26] who also reported the simultaneous presence of both positive and negative charges.

ANTISTATIC AGENTS

Many references are contained in the technical and patent literature to antistatic agents for preventing or dissipating electrostatic charges in plastics. With the exception of the radioactive types, which function by ionization, most of these materials are hydroscopic and absorb moisture from the atmosphere to form a conducting layer. Graham [27] has studied the factors involved in the reduction of static charges on nylon fibers by means of antistatic agents and found a peculiar periodicity in the per cent treating agent-voltage curves, often with a reversal of sign of the electrical charge.

ELECTROSTATIC PRECIPITATION OF ATMOSPHERIC DUST.

The principle of flocculation of smoke in an electrical field was discovered by Holfeld [28] in 1824. It remained for Cottrell [29] to make the first practical application of this principle in precipitating industrial fumes. In 1931 Penney developed a means of reducing the cost and size of the equipment and made other improvements so that it could be used to clean air in ventilating systems. In the electrostatic precipitators now used for the removal of dust from the air, all particles are electrically charged as they pass through a high voltage ionizer and are then attracted and adhere to collecting plates which carry an opposite charge. These units are highly efficient in removing even the finest sub-microscopic dust and smoke particles from the air, but they are also somewhat expensive for use in ordinary home heating and ventilating systems.

The question thus presented itself; **could not the electrostatic dust collecting ability of certain high dielectric plastics be utilized in air filters?** The evidence seemed to indicate that in the generation of "frictional" or static electricity the bodies involved must be solid or liquid. [3] The passage of a gas over a solid or liquid surface had not been found to produce any electrification unless dust particles or droplets were present. As Turkington [4] pointed out, static generated by discharge of carbon dioxide from cylinders is negligible unless solid particles are mixed with the gas. Thus when the cylinders were in an upright position no sparks resulted, but when inverted, sparks up to 3 inches long were obtained. We found that the initial residual charges on the surface of plastics were enhanced by the passage of air currents and potentials as high as 1,200 volts were obtained on certain plastics at an air velocity of 300 feet per minute. Since air filters embodying the use of such materials would not require a source of electrical energy in order to function as electrostatic precipitators of atmospheric dusts, they would be relatively inexpensive and properly considered as self-charging. Before discussing the practical aspects of such filters let us consider the nature of atmospheric dust and smoke.

THE NATURE OF ATMOSPHERIC DUST AND SMOKE

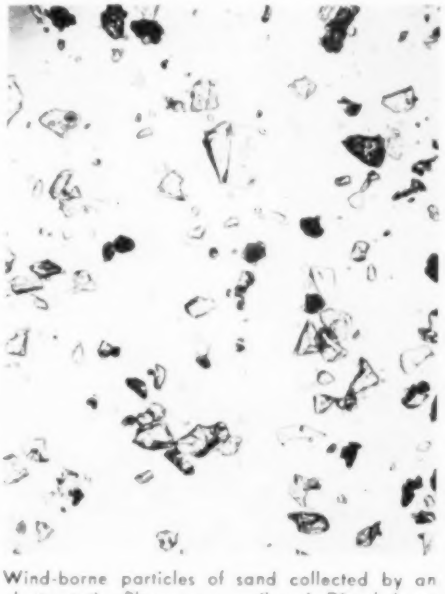
When dust is blown by the wind it becomes electrically charged. This phenomenon was studied by Rudge [30] who deduced four generalizations. Non-metallic elements give positively charged clouds when the finely-divided solid material is blown by a current of air. Metallic elements give negatively charged clouds under the same conditions, while acid-forming oxides give positively charged clouds, and basic oxides negatively charged clouds. In the case of salts the charge apparently depends on the relative strength of absorption of positive and negative ions.

The carbonaceous smoke particles present in a normal city atmosphere stay dispersed for long periods of time and are carried long distances by the normal movement of the air because of their small particle size, low apparent density, and the electrical charges which they carry. In general, smokes are characterized by particle sizes below 0.5 microns. Some of the particles may be positively charged and others negatively, depending upon the material of which they are composed and also on the manner of formation. [30] [31] Electrical flocculation experiments conducted by Lodge [32] on a cloud of smoke showed that in ordinary smokes about 30% of the particles are charged sufficiently to flocculate under the influence of a high-voltage alternating current.

Electrical charges in aerosols may be produced by friction of the particles rubbing together, by friction with the air, or by the action of an ionizing agent such as ultraviolet rays, ionic discharge from high-tension wires, or atmospheric disturbances. Because of these factors such particles are difficult to remove from the air by conventional filtration processes without employing a medium with undesirable air flow resistance characteristics at the velocities normally required in heating and ventilating systems. Furthermore, the amount of power required to force air through a filter with sufficiently small pore size to remove highly dispersed smoke is greatly in excess of that normally available in such systems.

It is the finely divided carbon present in the air in the form of smoke and soot that is responsible for most of the soiling of walls and furnishings in homes, offices, stores and other buildings. These highly dispersed and electrically charged particles become deposited on such surfaces by thermal or electrostatic precipitation [33] causing a great economic loss in cleaning and redecorating expense.

A study of atmospheric dust concentration in fourteen American cities made by the U.S. Public Health Service in 1936 showed that the average amount of sus-



Wind-borne particles of sand collected by an electrostatic filter on a railroad Diesel locomotive. The largest particle is 150 microns in length.

pended matter in the air during the winter months was 5.1 milligrams per 10 cubic meters, or 815 particles per cubic centimeter, of which 65% consisted of carbonaceous matter, 35% ash, 12% silica, and 2% iron oxide. The median size of the dust particles was found to be 0.58 microns and only a small percentage of the particles were more than 1.5 microns in diameter. The variation in particle size from city to city was found to be very small.

SELF-CHARGING ELECTROSTATIC AIR FILTERS

The materials listed in Table 1 have been observed to generate an electrostatic charge under the influence of an air stream and collect dust from the atmosphere by electrostatic attraction to a greater or lesser degree.

Among the materials that have been found to exhibit this phenomenon are those which can be formed into thin films by calendering, extrusion, or casting from solution and then shredded to form a porous mass. They can also be extruded and drawn into filaments or fibers similar in size and shape to the glass fibers employed in air filters. Materials which cannot be readily obtained in film or fiber form, such as some of the plastics and the various waxes and resins, can be coated from solution or dispersion on a porous or fibrous material such as glass, vegetable or animal fibers, and shredded paper, to impart electrostatic properties to the type of filter masses presently employed in air filters.

The plastics that are most suitable for use in electrostatic air filters develop both positively and negatively charged areas in the same mass and will, therefore, attract and retain both types of charged particles. As some dust particles carry a negative charge and others are positively charged the possibility of using two electrostats of opposite average polarity in an air filter was considered. It was found that polythylene and Pliofilm carry an opposite balance of charges, which can be demonstrated by bringing charged streamers of these two materials within their spheres of influence. Under these conditions they are mutually attractive, showing that they are of opposite sign. However, a filter constructed of layers of these two materials was no more effective than one made of polyethylene alone.

Some plastics will collect dust even under conditions of high humidity. ([33]) According to Von Hippel the surface resistivity of polystyrene does not decrease with increase in relative humidity and polyethylene shows only a slight decrease, the insensitivity of the electrostatic properties of polystyrene to moisture has been demonstrated by Woodland and Ziegler, ([33]) and also by Weber and Flammersfeld. ([34]) Air filtration efficiency tests conducted in our laboratory showed humidity to have no significant

Table 1

Materials Capable of Collecting Dust From The Atmosphere by Electrostatic Attraction

Rubber hydrochloride	Polyamide resins
Cyclized rubber	Polytheylene
Chlorinated rubber	Polystyrene
Polyisobutylene	Fluorinated ethylene
Polyacrylonitrile	polymers
Vinyl chloride polymers	Methyl methacrylate
and copolymers	Ethyl cellulose
Vinylidene chloride polymers	Melamine resins
& copolymers	Urea resins
Cellulose nitrate	Phenolic resins
Cellulose acetate	Natural resins
Regenerated cellulose	Waxes

Table 2

Laboratory Smoke Filtration Tests

Material	Grams of smoke retained per 20 grams fuel burned
Oil coated glass fibers (Control, not electrostatic)	0.0[illegible]
Polyethylene-shredded film	0.2[illegible]
Polyethylene-coated on glass fibers	0.3[illegible]
Polyethylene-shredded film coated with glycerine	0.047
Polystyrene-coated on glass fibers from latex, fused	0.3[illegible]
Polystyrene-coated on glass fibers from solution	0.228
Polyamide fibers	0.213
Polyvinylidene chloride-shredded film	0.079
Polyvinyl chloride-shredded film	0.044
Rubber hydrochloride - shredded film	0.047

effect on polyethylene. It was found, however, that dielectric materials which contain polar groups, such as rubber chloride and hydrochloride, cellulose acetate and nitrate, tend to be sensitive to high atmospheric humidity and either do not build up a sufficient electrostatic charge, or the charge developed is rapidly dissipated. The net result is that such materials are not effective electrostatic dust precipitators under conditions of high humidity.

Radioactive materials such as polonium and uranium, which emit rays that ionize the atmosphere and produce electromagnetic effects, will discharge the electrostatic filters and render them ineffective.

The evaluation of air filter efficiency by means of atmospheric dust is a rather slow process and an accelerated test was desired in order to evaluate the various electrostatic plastics as practical dust collectors. It was found that an aerosol of fine smoke could be generated by burning in a mixture of alcohol and benzene under controlled conditions. (Figure 2) Using this as a source of smoke, filtration tests were conducted on various electrostatic materials at 300 fpm air velocity. Some results of these tests are shown in the following table.

The oil coated glass fiber material used in these tests was from a standard commercial impingement filter, which is the type most commonly used in heating, ventilating and air conditioning systems. The effect of surface area on the smoke collecting efficiency of polyethylene will be noted by comparing the shredded film with the coated glass fibers. Coating the shredded material with glycerine dissipates the electrostatic charge and reduces its efficiency to the level of an impingement filter. The low smoke collecting efficiency of polyvinylidene chloride, polyvinyl chloride and rubber hydrochloride is believed to be due to the polar nature of these plastics which reduces the amount of electrostatic charge developed under the humidity conditions of the test.

In addition to surface area, the nature of the surface is a factor in determining the dust and smoke collecting efficiency of electrostatic materials. Serrated or fuzzy edges, as shown in Figure 4, serve as centers of attraction and are much more effective than smooth surfaces.

Not only are these electrostatic materials effective in attracting and retaining fine particles of dust and smoke, but they have also been found to be effective at the other end of the dust spectrum. Practical tests have shown that

(Please turn to page 43)

open door to better service

— with C-11 plastics

The door of every new Servel "Automatic Ice-Maker" refrigerator carries three shelves on its inner side. Shining and clean-lined, they accent the interior's up-to-the-minute styling. Molded from BAKELITE C-11 Plastics for toughness, they'll hold bottles, cans and jars of foods used most.

The shelves are molded to sharp detail in one minute between 580 and 660 deg. F. Each weighs only eight ounces. Spraying the underside with gold paint gives them their rich metallic luster. For attachment to the door, they have studs molded with holes that become self-threading when screws are inserted.

BAKELITE C-11 Plastics are acrylonitrile-styrene copolymers that have several features distinct from both acrylic and styrene plastics. One such feature is strength—their tensile and flexural strengths are 45% higher than those of standard polystyrenes. Another is durability—they withstand contact with tea, coffee, citrus peels, soaps, detergents, oils, cosmetics. Their dimensional stability is excellent.

With this combination of properties, BAKELITE C-11 Plastics are extending the usefulness of plastics in such fields as housewares, packaging, product design. For more information about them, write Dept. PI-43.

Door shelves for the Servel "Automatic Ice-Maker" Refrigerator molded by Kusan, Inc., Nashville, Tenn.

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Tomorrow's

Roll Surface Temperature Control and New Press Heating Systems

Paul L. Geiringer
Chief Engineer
American Hydrotherm Corp.

Presented at the 9th SPE Conference

HEATING BY MEANS of high temperature liquids applied to plastic sheeting, pressing, and molding is a dream which has been materializing during the 25 years which I have devoted to pioneering this ideal type of heating system.

The application of high temperature liquid phase heating to the plastics field is of particular interest inasmuch as its inventor, Mr. Klingelhoefer, designed the first liquid heating system as early as 1924 with a view to improving the process of pressing plastics material. His work resulted in the use of high temperature water heating in the enormous Bakelite plant in Troisdorf, Cologne, Germany. During the last five years many industrial plants in this country changed over from steam heating to high temperature water heating. Where higher temperatures are required, organic liquids have been used as heat carriers.

The plastics sheeting and coating industry is fast entering into a new phase of its development. The demand for higher production, better uniformity of the product and economy of operation has led to wide acceptance of high temperature water and other liquid heating media. Existing equipment is rapidly being converted and new designs almost universally incorporate these superior heat carriers in preference to steam.

When we first introduced, based on our European experience, high temperature liquids in this country, we considered it to be an innovation which could make substantial improvements worth the consideration of users. Hardly did we realize how little time would pass before these liquid heat carriers would be considered a necessity. We emphasized the large fuel savings inherent in the use of closed circuits, the ease of obtaining exact temperature control, and the valuable heat accumulation capacity associated with liquid heat carriers. There are, however, other advantages of liquid heat carriers

Paul L. Geiringer

which apply especially to the plastics industry and which result in greater uniformity of the plastics product, and also in greatly increased production speeds. These features are becoming well known. Calender and press users who continue to use somewhat old fashioned steam for heating their equipment, thinking that it would be too costly to convert, are fast coming to realize that there are new and imperative reasons for changing to more modern heat carriers and control systems. High temperature liquid heating can no longer be considered to be a luxury, but rather is recognized as a necessity.

CALENDER HEATING-COOLING

WHY HAVE LIQUID HEAT CARRIERS BEEN PROVEN TO BE A NECESSITY FOR SHEETING AND FILM CALENDERS?

1. The constant improvement in the quality of product which a manufacturer requires to keep his competitive standing is only possible with liquid heat carriers. This was proven by the introduction of Beta Ray gages. They have detected the relative non-uniformity of sheeting produced with steam heated calenders. The uniformity in thickness of sheets produced by high temperature liquids cannot be equaled by calenders using steam.

2. Roll speeds higher than 45 to 50 yards per minute cannot be used for many plastics materials without resorting to cooling of the rolls, and this cannot be accomplished satisfactorily with steam. Only liquids make high temperature cooling systems practical and economical.

3. The cost of conversion is being reduced because of the expanding market and the extensive experience acquired in recent years, and because simpler and more compact designs are available.

WHY IS A STEAM HEATED CALENDER COOLED BY WATER INJECTION NOT PRACTICAL?

The answer is very simple. Hardly any roll heated by steam can withstand the stress created by the thermal shocks created by uncontrolled water injection.

The United States Rubber Company has been kind enough to permit me to show you some pictures which will illustrate this point very nicely. The story behind these pictures has its counterpart throughout the plastics industry.

Figure 1 shows a cracked calender roll. Such cracked rolls are costly to replace and represent substantial losses in production time and material. For a long time many companies have used water injection, disregarding the resulting high fuel cost. Even so, from time to time their operators, in their desire to reduce the cooling period, have cracked the rolls by injecting the water too rapidly.

For proof of this theory let us examine the next picture, **Figure 2**. This shows a cross section of a cracked roll. We can see a corroded section of the cracks near the hub on the inside of the cylinder. This indicates that the crack started here

due to excessive cooling of the metal. The crack grew deeper during successive cycles until it reached the outside surface. We have further to point out that through water injection the interior of the rolls is soon coated with scale, inhibiting uniform heat transfer. The inside cleaning with chains or other means is neither easy nor successful.

It is a fact that several companies are operating their calenders at high speeds and resort to cooling the rolls by either reducing the steam pressure or by gradual introduction of cooling water. The first method cannot possibly be efficient since the cooling thus achieved is very limited. The latter method may be workable but is very uneconomical inasmuch as steam mixed with water is constantly being used to blow through the rolls.

In a high temperature water system no steam is wasted, once the desired temperature in the system is reached. Cooling or mantaining that temperature requires no waste of heat but only cooling water.

It is thus evident that steam heating of calender rolls cannot be adapted to modern requirements by the expedient of water injection. Only liquid carriers can be used for this purpose, and their use in high temperature systems will also avoid thermal shocks.

About five years ago we introduced high temperature water to the plastics industry, installing the largest calender built to that time. It had drilled rolls, 24 inches in diameter and 68 inches long. Since that time considerably larger calenders of 32 inches diameter and 92 inches in width have been equipped by us, using our Hydrotherm high temperature water system.

More and more drilled rolls were introduced in order to increase the usable width of the calender roll, since cored rolls suffer a temperature drop at the ends due to the increased thickness of the metal near the ends. Drilled rolls are especially well suited to high temperature liquids, but have not been found to solve the problems associated with steam heating. However, high temperature liquids also perform well with cored rolls.

Having more than 20 years experience with this heat carrier, our engineers recommended high temperature water in the first installation, because they knew that only liquid heat carriers could secure the uniformity of temperature over the entire roll surface necessary to guarantee a good product.

We were sure that very close temperature control could be achieved and continuously maintained, even within 1 degree F or less. Since the purchasers of our first installation did not fully believe our claim of temperature control and uniformity, these installations were equipped with much more instrumentation than was actually necessary. Simplification in this respect has since become possible. This has helped to lower the price considerably. Our present policy is to reduce the instrumentation to a bare minimum. We even have in operation a smaller calender installation with manual control. In this calender installation we could prove that a temperature setting of plus or minus 2 degrees F is possible manually, requiring, however, readjustment from time to time. This installation, however, proved the great heat accumulation capacity of liquid heat carriers.

In the last few years we have further advanced the art of high temperature liquid heating by compressing our installations into a much smaller space, of 10 feet x 20 feet, and in many cases into even smaller "Packaged Units."

In the early days of high temperature liquid heating many people were afraid of this new venture. Now I would say that the tendency is to the contrary. Many people think it is too easy and are tempted to design and instrumentate high temperature liquid systems for calender and press heating and cooling without consulting those who have learned through many years of experience how to avoid certain dangerous pitfalls.

I am pleased to see the interest in these heat carriers which is reflected in the number of designs of these systems which are commercially offered. I should like to warn, however, those who think they can put a simple sketch into practice cheaply and without incurring trouble. First of all, these designs do not necessarily represent the experience which is available in the art, and nobody will take full responsibility for them. Actually, many of these designs will result in failure or in greater costs even if the system did work. Properly designed systems are now available at very reasonable costs and, in addition, the users are denying themselves the use of experience and of new patented devices which are improving these systems.

TYPES OF SYSTEMS

Figure 3 shows two types of calender heating-cooling systems which are used, one serving an individual roll, the other serving a number of rolls and calenders. Controls of various types are shown, providing any

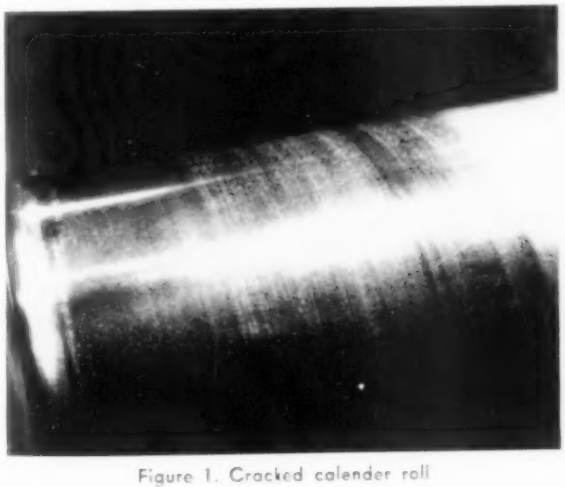

Figure 1. Cracked calender roll

Figure 2. Cross section of cracked calender roll

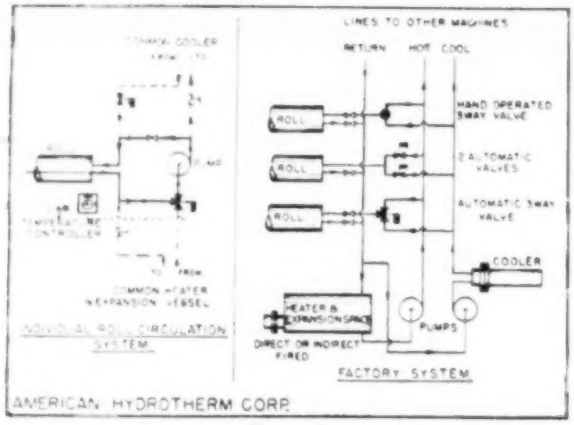

Figure 3

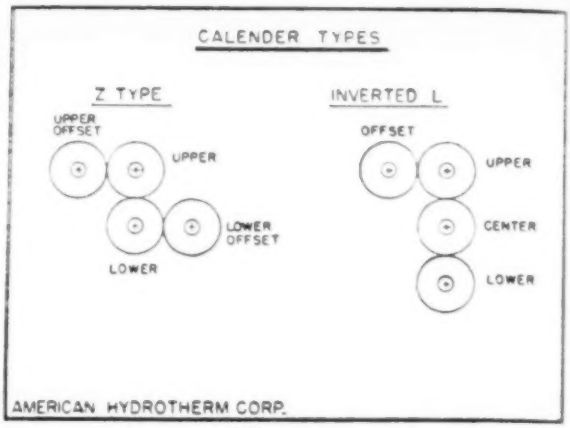

Figure 4

desired temperature of the water entering the rolls by mixing hot and cool water.

THE PROBLEM OF SURFACE TEMPERATURE CONTROL AND MEASUREMENT

There are two main problems associated with obtaining the precise temperature regulation required for producing a uniform product from calenders:

1. Obtaining the **desired** surface temperature at different calender speeds.
2. Maintaining a **uniform** temperature over the entire surface.

The problem of maintaining uniform surface temperatures is solved by the use of high temperature liquids and a correct design.

The other problem to be solved is that of obtaining and maintaining a certain prescribed surface temperature regardless of whether the calender is to be heated or cooled.

I have previously mentioned the fact that high calender roll speeds require cooling of certain if not all of the rolls of the calender. For instance, consider the L-type and Z-type calender shown in **Figure 4**. The plastics material passes between the offset roll and upper roll, then between the upper and center roll and finally between the center and lower roll. The upper rolls pregage the plastics sheet and the lower ones widen it and produce the desired thickness. At high speeds the frictional work done by the lower rolls requires that they be cooled, while the upper may have to be heated. If a roll is to heat the plastics material, water at a temperature above that of the desired roll surface temperature must be circulated, and when cooling is desired, water at a temperature below that prescribed for the roll surface must be circulated. But how can the water temperature be selected and how can the surface temperature be measured?

Measurement of surface temperature must be accomplished by some device, either direct or indirect, before a control is possible.

DIRECT MEASUREMENT OF SURFACE TEMPERATURE

Direct measurement of surface roll temperature has met with grave if not disastrous difficulties. For the measurement of surface temperature, instruments were designed which depended upon a rubbing contact with the fast moving surface of the roll. However, rubbing friction can cause an error, and dirt or plastics material can break the contact with the surface. Even if the thermal element is kept 1/32 of an inch off the surface, the picture is not changed for the better. We also tried to actuate control instruments from these surface gages, but had no luck.

These difficulties caused controls based on direct surface contact to perform poorly. For this reason we abandoned the direct in favor of the indirect method of control, a method which we invented and devised.

INDIRECT MEASUREMENT AND CONTROL OF SURFACE TEMPERATURE

Our indirect method of surface temperature control relies upon a measurement of the quantity of heat flowing from or to the roll. This quantity of heat is readily indicated by the temperature difference between the inlet and outlet water temperatures of the circulating liquid, provided that nearly constant water circulation is maintained. (turn page)

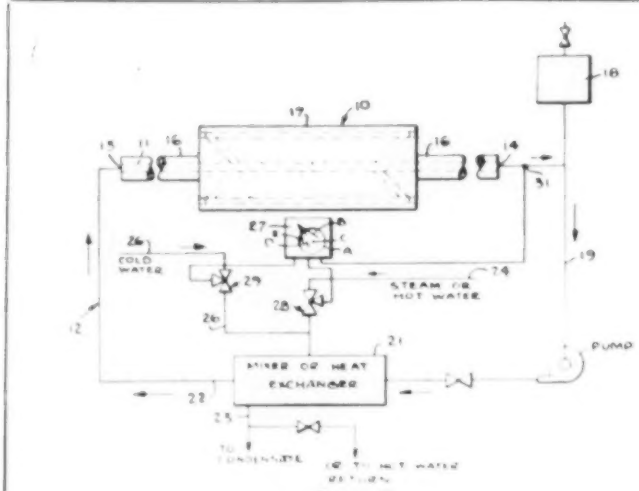

Figure 5

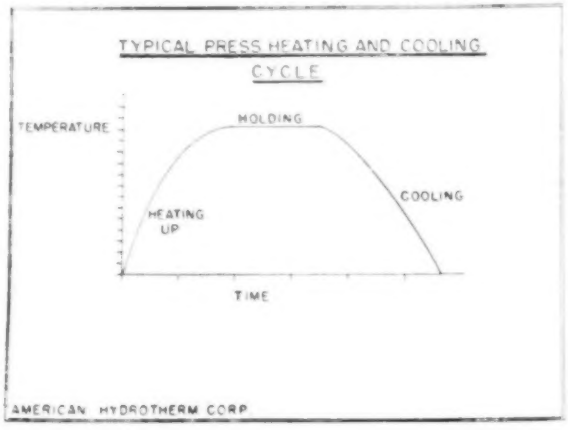

Figure 6

Figure 5 shows a drawing of a surface temperature measurement circuit. Incidentally, patent has been applied for.

The average surface temperature differs from the average water temperature by an amount proportional to the heat flow. If the roll is being heated by the circulating fluid, the fluid temperature must exceed the surface temperature. If the heat flow is doubled, for instance, the fluid temperature drop, passing through the roll, will also double, and at the same time the mean temperature difference between the circulating fluid and the surface will double. In order to maintain the same surface temperature at a doubled heating rate, the inlet water temperature must be raised accordingly. If the heat flow is reversed so that the roll is cooled by the fluid, the temperature difference will reverse and the inlet water would have to be adjusted to a temperature below that of the surface.

These functions can be carried out by a control system which measures the inlet and outlet fluid temperatures, and which can be set to maintain any desired surface temperature, at all times responding to the actual quantity of heat flowing into or out of the roll. This control method has been successfully developed by us.

CAN THE SURFACE TEMPERATURE BE MEASURED INDIRECTLY?

Yes. An additional component of this control system has been developed to indicate the average surface temperature. This indirectly measured surface temperature can also be used to control the heat input and output of the roll by varying the inlet water temperature. An instrument for this purpose will soon be available.

PRESS HEATING-COOLING

High temperature liquids are also advantageous when applied to the heating of press platens. Many of these advantages apply equally to calender heating and have already been discussed, but others are particularly significant in press applications:

1. Uniform surface temperatures can be attained.

2. Exact temperature control in both heating and cooling cycles is possible.

3. Temperature cycles can be designed and maintained to meet the needs of the press operation. Transfer of heat from the metal surface can be performed at a rate which corresponds to the rate of the process.

4. Accumulators can be used to even out the load on the boiler so that the boiler does not have to absorb the peak press heat load at any time.

A temperature curve with respect to time is shown in **Figure 6.** Cycles of this sort are commonly required in plastics presses and, as you can see, require both heating and cooling of the press platen.

DISADVANTAGES OF USING STEAM FOR PRESS HEATING

Steam cannot produce **automatically** a controlled heating and cooling cycle such as we have shown in **Figure 6.** A comparison of surface uniformity of steam and water heated platen is shown in **Figure 7.**

As we have previously pointed out, cycles of this sort can be achieved automatically only with liquid heating systems. With high temperature liquids such cycles can easily be maintained by automatic program control instruments.

A number of reasons have motivated press users to convert to high temperature liquids. Some have done so to reduce fuel costs, some wanted to take advantage of the close and flexible temperature control or the shorter heating and cooling cycles. A further and especially attractive reason for conversion is the result of

(Continued on page 51)

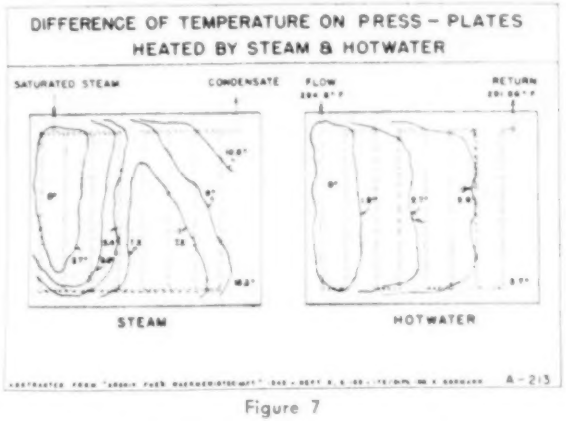

Figure 7

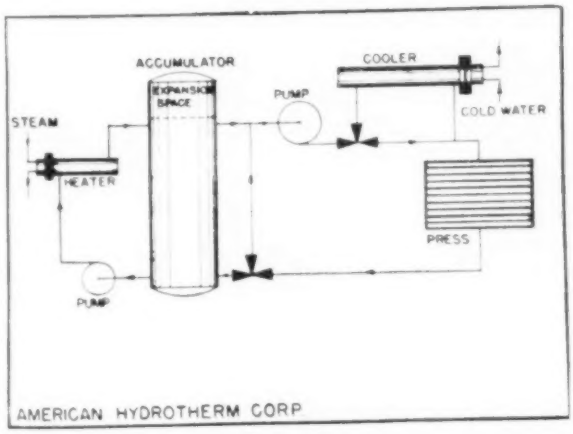

Figure 8

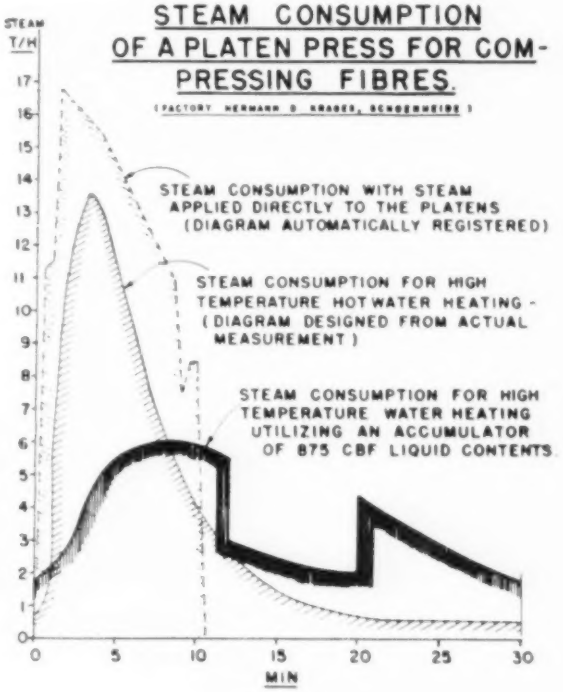
STEAM CONSUMPTION
OF A PLATEN PRESS FOR COMPRESSING FIBRES.
(FACTORY HERMANN D. KRAGES, SCHOENWEIDE)
STEAM T/H
STEAM CONSUMPTION WITH STEAM APPLIED DIRECTLY TO THE PLATENS (DIAGRAM AUTOMATICALLY REGISTERED)
STEAM CONSUMPTION FOR HIGH TEMPERATURE HOTWATER HEATING - (DIAGRAM DESIGNED FROM ACTUAL MEASUREMENT)
STEAM CONSUMPTION FOR HIGH TEMPERATURE WATER HEATING UTILIZING AN ACCUMULATOR OF 875 CBF LIQUID CONTENTS
0 5 10 15 20 25 30
MIN

Figure 9

Vinyl Floor Coverings

Robert K. Petry
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Presented at the 9th SPE Conference

THE SMOOTH SURFACED resilient floor covering industry, as we know it today, started in England with Walton's development of linoleum in the early 1860's. His patented process, using oxidized linseed oil and natural resins as a resilient binder for pigments and fillers is basically unchanged in today's linoleum manufacture. Durability, ease of maintenance and comfort underfoot were primary factors in the rapid, world-wide expansion of the linoleum industry.

As the use of linoleum increased and the advantages of a smooth surfaced floor covering gained recognition, new types of flooring products appeared. For many years the popular enamel surfaced floor coverings were printed on a thin sheet of linoleum. In 1911, however, the roofing industry, seeking new uses for their products, started the first production of printed felt base, in which the linoleum was replaced by a sheet of asphalt saturated felt. Printed enamel felt base, with its wide variety of designs and colorings, good serviceability and low initial cost, has for many years been the largest volume product in the flooring industry. Today asphalt saturated felt has also replaced fabric as a supporting base for linoleum, in all but a few specialized products.

The first commercial production of asphalt tile occurred in 1922, and within ten years, eight firms were manufacturing this product. During World War II, when raw material shortages restricted the production of linoleum, the use of asphalt tile rapidly increased. Its satisfactory performance on concrete slab floors in direct contact with the ground and its relatively low initial cost have increased the use of this product till today its annual production volume is about equal to that of linoleum.

Rubber tile was introduced as early as 1905. Its beauty, resilience and long service life have given it recognition as a superior quality product, but high cost has been a limitation to widespread use.

In the early 1930's it was recognized that vinyl resins had many inherent attributes which were well suited to flooring applications. Resin costs of more than one dollar per pound were far too high for commercial production, but evaluation of experimental vinyl floorings started. The earliest known vinyl floor installation was made in 1931. This was a tile floor produced from the low molecular weight vinyl resins. It was installed in a recreation room, below grade, and is still in service. In 1933 a similar vinyl tile floor was installed at the Chicago World Fair. Afterwards, this floor was removed and relaid in several new locations, some of which are still in use.

Robert K. Petry

Between 1937 and 1940, with vinyl resin costs down to fifty-five cents per pound, several flooring manufacturers produced limited quantities of this type of vinyl flooring. These were the hard, semi-flexible tiles, made on asphalt tile equipment. Because of processing limitations involved with this equipment and the difficulty of incorporating large quantities of filler in the high molecular weight resins, only the low molecular weight vinyls were used.

World War II interrupted commercial production of vinyl floorings, but the tremendous interest generated in vinyl products of all kinds during the war stimulated a considerable amount of development within the flooring industry.

Shortly after the war, with resin costs at thirty-three cents per pound, flexible vinyl tiles made from the higher molecular weight resins were introduced as an addition to the semi-flexible type. In 1947 and 1948 laminated vinyl floorings of the calendered and printed types were introduced in roll form, up to nine feet wide. Today more than twenty manufacturers are producing vinyl flooring in its various forms.

Early vinyl floorings were beset with many difficulties, both in processing and in finished product quality. A wide variety of resins, plasticizers and other raw materials required tedious evaluation to develop satisfactory formulations for floor service. In most cases special techniques had to be developed to process the vinyl compounds and to provide the desired decorative effects. Frequently existing equipment had to be modified or entirely new machines designed to suit the newly developed process. Both solid tiles and laminated floorings were not dimensionally stable, frequently resulting in seam openings on the floor. Adhesives used for bonding the laminated floorings often failed, as did many of the installation adhesives used to cement solid tiles to the floor.

Improvements in formulation and processing techniques soon overcame these early deficiencies. The "plastic conscious" public, looking for new and improved products readily accepted vinyl floorings. Recognition of quality, together with lower prices from increased production volume and lower material costs rapidly expanded the market for vinyls.

Vinyl floor coverings available today may be divided into two major classes—the unsupported or solid vinyls and the supported or laminated products.

The solid vinyls are homogeneous compositions throughout their entire thickness and are supplied mainly in tile form, from 1/16" to 3/8" in thick-

In most cases they are available in a variety of colors and decorations. These solid vinyl tiles are further divided into two types—the flexible and semi-flexible.

The flexible vinyl tiles represent the highest quality and, incidentally, the highest priced vinyl flooring product made commercially. They consist of about 50% of a plasticized high molecular weight vinyl chloride polymer and 50% color pigment and filler, together with the necessary stabilizers, lubricants, etc. Their method of manufacture generally follows that of rubber tile, in that they are mixed, sheeted and pressed to a smooth glossy surface, sanded on the back to correct gauge, and die cut into the desired tile size. Such products are very durable, having a high degree of resistance to abrasion, chemicals, water and grease. Their color range is practically unlimited and they may be installed on any type of floor, such as suspended wood or on concrete, on or below grade. They are resilient and comfortable under foot, fire resistant and require little maintenance.

The semi-flexible tiles are particularly well suited to installation on concrete floors, both on and below grade, where a more durable and higher quality product than asphalt tile is required. They also have excellent grease and chemical resistance and are available in a wide range of bright and pastel colors. The manufacturing process closely follows that of asphalt tile and consists of mixing, sheeting and calendering to gauge, after which the tiles are die cut while still warm, cooled and packed. The lower molecular weight vinyl copolymer resins from which they are made will tolerate as high as seventy-five percent total filler. This, together with low processing costs, brings the semi-flexible type tiles into a lower price range than the flexible type, and naturally results in much larger volume use. The growth of this product accounts for a major portion of the increase in vinyl flooring production in the past year.

The laminated vinyl floorings consist of a vinyl wear surface on a supporting base, and are divided into two categories—the calendered and the printed types.

Those having a calendered wear surface are usually made in both tile and roll form. The vinyl wear surface is similar in composition to that used in the flexible vinyl tiles, but is thinner, varying from .020" to .040". The supporting base may be flooring felt or a relatively low cost plastic sheeting from .040" to .060" thick. Suitable fabrics may also be used. Such products are priced competitively with linoleum and are receiving good acceptance, particularly for domestic use. Today they represent by far the largest volume class of vinyl floorings.

The vinyl wear layer has all the quality advantages of the more costly flexible vinyl tiles, except that service life is largely dependent on the wear layer thickness. The felt backed products may be installed using conventional methods and adhesives developed for felt backed linoleums. The wear surface is produced in a variety of multicolor decorations by specialized calendering techniques. The manufacturing process consists of a continuous calendering operation for forming the decorated wear layer, followed by lamination to the supporting base. The finished product is packed in rolls or cut into tiles.

Printed vinyl floorings consist of two basic types—one in which the printed design is protected by a transparent vinyl wear layer — the other in which the design colors comprise the wear layer. Both use vinyl resins in dispersion form.

In the transparent wear layer type, the design is printed with vinyl inks by the rotogravure process on a thin sheet of paper, specially treated for water resistance and flexibility. The printed paper is then coated with the vinyl wear layer, applied from an organosol dispersion. The dispersion coating is dried and fused at elevated temperatures to a tough, continuous film. The coated design sheet is then adhesively laminated to the supporting felt base.

This type of product has practcially unlimited styling possibilities, in that any design can be photographed with good fidelity. The durability and, to a considerable extent, the cost of this type product is proportionate to the thickness of the protective wear layer, which ranges from .004" to .010". Since the manufacturing operations can be performed at relatively high speeds, and even thin vinyl films provide good durability, the rotogravure printed vinyl floorings offer great possibilities for a highly styled, serviceable flooring in the large volume, low priced field.

The second type of printed vinyl flooring involves the application of a vinyl paint to a supporting felt base. The patterned wear layer may be printed from a pigmented vinyl latex or organosol in a film thickness of four to five mils, and fused at elevated temperatures according to the requirements of the particular formulation. This process has the advantage of using the conventional flat bed printing equipment of the floor covering industry. Printed vinyl films of this type possess the good characteristics of vinyl resins, but are limited to the same decorative effects and slow production speeds of the regular enamel felt base.

The variety of vinyl floor coverings introduced in recent years and the rapid growth of most of them has been little short of phenomenal. There are many good reasons for their success to date and for the predictions of greatly increased volume in the future.

Vinyl floor coverings have demonstrated remarkable quality in service. Properly designed for the application they will outwear any of the conventional resilient floorings. Their initial color range and permanence of color are limited only by the pigments which are available. They are outstanding in their superiority to other resilient flooring products in chemical, grease and water resistance. They can be made hard or flexible and retain all of these characteristics without appreciable deterioration in storage or in use.

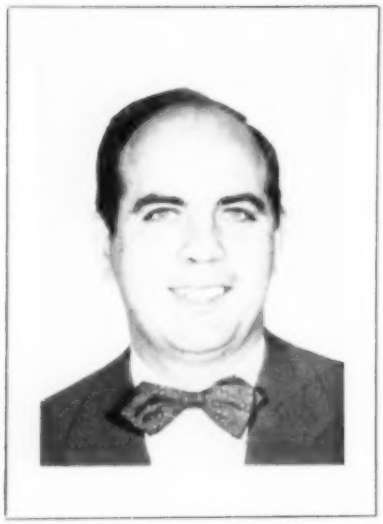
Processing time of calendered vinyl floorings is short. No prolonged curing or stoving is required to convert the product to usable form. This eliminates the need for large and costly in-process inventories. Since the material is thermoplastic, scrap and rejected material can be reworked without loss. The conversion of coated or printed types of vinyl flooring requires only a few minutes to elevate the temperature to the fusion point. These low processing costs are important factors in the growth of vinyl flooring products.

Obviously, vinyl resins are extremely versatile materials. In floor coverings, as in many other fields, they can be used in a number of forms to produce a wide variety of finished products. Since they can be applied in so many ways—from liquid solutions, emulsions and dispersions to hot melt form—all resulting in finished products of good durability, they are particularly well suited to the manufacture of the variety of products required by the smooth surfaced flooring industry.

A few years ago the growth of vinyls was the cause of some concern within our industry, since they foreshadowed the possible obsolescence of existing manufacturing facilities. High molecular weight vinyl resins could not be processed on conventional equipment. However, the development of vinyl resin dispersions in various forms, permits processing those materials in high concentrations at reduced pressures and temperatures, since the dispersion resins are not in a solvated form during the processing operation. This opens wide the field for development of vinyl flooring products adapted to processing on existing equipment. This is now a further incentive to upgrade quality with these amazing and versatile vinyl materials.

Since raw materials represent the major portion of the finished cost

(Please turn to page 60)



Techniques of Moldi ng

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Presented at the 9th SPE Conference

INTRODUCTION

Considerable technical information has been published regarding the chemistry and the physical properties of polytrifluorochloroethylene. Therefore, this paper will deal primarily with the conditions of its use as a thermoplastic resin in the injection and compression molding industry. However, it would probably be well to review briefly some of the forms in which this polymer exists and a few of its major physical properties.

Polytrifluorochloroethylene is polymerized from purified monomeric trifluorochloroethylene in the presence of a peroxide catalyst under carefully controlled temperature and pressure conditions.

The polymer exists in various forms from a low molecular weight light oil to a high molecular weight solid plastic material, as shown in Fig. 1. As we are mainly concerned with the molding powder forms, we will only consider the higher molecular weight compounds. This polymer is currently produced by The M. W. Kellog Company in Jersey City, New Jersey, and sold by them under the trademark KEL-F*. We refer particularly to Kellogg's KEL-F brand molding powder grade 300, etc.

As polytrifluorochloroethylene is a "lot of word" to keep repeating, and since our work has been exclusively with our own KEL-F brand product, we shall hereafter refer only to KEL-F.

Both grades of KEL-F are produced as low density molding powder (approximately 19 lbs. per cubic ft.) and high density molding powder (approximately 60 lbs. per cubic ft.). These grades of polymers can also be plasticized with lower molecular weight oils and waxes.

The high density powder is composed of granules approximately $\frac{1}{8}$" in diameter and $\frac{1}{8}$" long. The low density molding powder consists of a much finer powder, approximate 20-30 mesh. In its natural state at ambient temperature, the powder has a milky white color and as it is gradually heated to its plasticizing temperature, the color changes from a milky white to a clear transparency as it reaches the transition temperature of 415°F (213°C). This change of color indicates that the structure of the material has changed from a partially crystalline form to an amorphous form. These two forms are shown in Fig. 2. If the material above the transition temperature of 415 F (213°C) is cooled slowly to ambient temperature it will again regain somewhat the milky white appearance. However, if it is quenched rapidly through the transition temperature of 415°F (213°C), the molecular chains remain in a random state and the material will retain its transparent appearance, indicating an amorphous state.

Constant mention will be made to the grades 300 and 270 molding compounds, therefore, we should know what these numbers mean. As the behavior of the various grades of polymer are related to the molecular weight, a method of determining this value is required to control the manufacture of the polymer and finished fabricated item. Since the actual molecular weight of a polymer is difficult to determine and since the molecular weight is related to the viscosity of a polymer, a viscosity measurement can be used for control of the polymer and fabricating process. There are several methods of determining viscosity of a plastic material, the one used by the M. W. Kellogg Company for KEL-F being a solution viscosity method. This test is described in a report by the M. W. Kellogg Company and consists of putting a very small

TABLE I

TABLE OF GENERAL PROPERTIES

Specific Gravity	2.1
Thermal Conductivity gr. cals sec. cm^2/°F. cm	1.44×10^{-4}
Specific heat-granular form	0.216
Water absorption	0.00%
Water vapor transmission 3.8 mils sheets gr/100 sq. in. 24 hrs. at 100°F. and 95% R. H. differ.	0
Chemical resistance — all acids, alkalies, fluorine, fluorides	
Index of refraction	1.43
Non-inflammable	

**The M. W. Kellog Company trademark for polymer produced by it.*

Polytrifluorochloroethylene . . .

quantity of molding powder or polymer in an aromatic hydrocarbon solvent at an elevated temperature and measuring the viscosity of the solution. However, this method of measurement of viscosity is not practical for use by a polymer production unit or a molder of KEL-F. Therefore, a method called the No Strength Temperature test or NST, was developed and is directly related to solution viscosity.

This test consists of determining the temperature at which a standard sample will fail under essentially no load. To perform the test, a sample of the polymer or fabricated part is pressed into a 1/16" thick disc. A strip 1-3/8" long x 1/8" wide is then cut from this disc with a double notch cut 1" from the end of the strip in order to give a cross-section of 1/16" x 3/64" at the notch. A weight is then attached to the 1" end to give a total weight of plastic and added weight from the notch down of .5 grams (See Fig. 3).

The sample is then suspended in a heated atmosphere provided by the apparatus shown in Fig. 4 and the temperature raised 1½°C per minute until the sample breaks at the notch. The temperature of the oven is then read as the No Strength Temperature or NST value. A difference of plus or minus 5°C is normally considered significant when comparing different sets of test apparatus.

The grade numbers of the molding powder are then classified as grade 300 being nominally 310°C NST and grade 270 being nominally 270° NST.

Table I shows some of the general physical properties of this material. Its resistance to inorganic solutions and compounds is excellent. It is equally resistant to most organic solvents and compounds but is slightly swelled and plasticized by some highly halogenated materials and aromatics. This will generally be of a minor nature. It has zero moisture absorption, extremely low moisture vapor transmission rate and resists wetting by water. It has an excellent anti-sticking surface and therefore no known cement is available for KEL-F. It has good electrical properties over a range of high and low frequency. It has a high tensile and impact strength over a wide range of temperature. It is also transparent to light rays in the near infrared region.

At this point we might look at several molding applications showing where the various physical properties, such as chemical inertness and chemical resistance, combined with mechanical strength are required. Figures 5 through 9 illustrate some typical applications.

Further reference will be made to these parts in a latter part of this paper giving data concerning their fabrication.

The first consideration given in the molding of KEL-F is cleanliness. This material is packaged in polyethylene lined drums up to a maximum of approximately 250 lbs. capacity. Before the metal cover is placed on the drum, a polythylene sheet is laid over the top of the material. This is to prevent any particles from flaking off the metal cover and dropping into the molding powder. When the drum is received at the molder's plant, it should be stored in a clean, dry location. Before the drum is opened, it should be wiped with a clean rag and care

Figure 1. Samples of Kel-F polymers

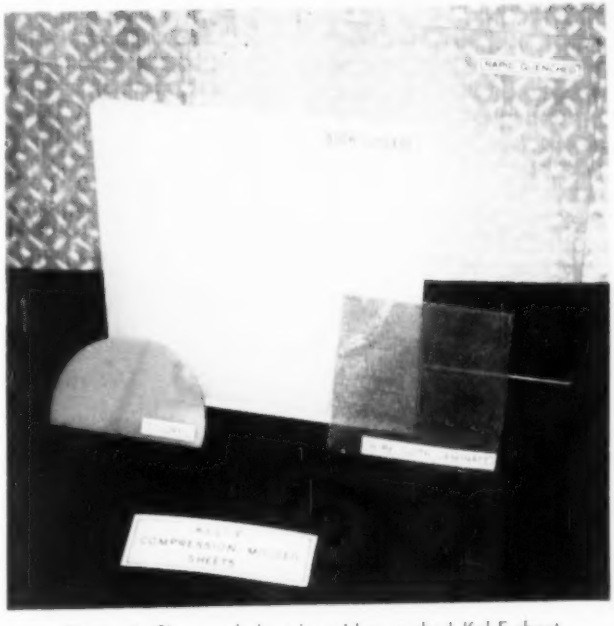

Figure 2. Slow cooled and rapid quenched Kel-F sheet

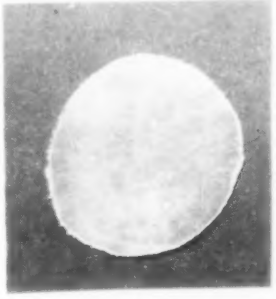

Figure 3. No-strength test samples

should be taken when the cover has been taken off, that dirt and dust from the outside does not fall into the molding powder. After the drum has been opened, the material should be removed from the drum to the hopper scale or mold by means of a metal scoop or plastic container, which has been thoroughly cleaned. After the required amount of material has been removed from the drum, the cover should be put back on top of the drum immediately to prevent any foreign material from contaminating the molding powder.

The same cleanliness that applies in the handling of the containers applies to the press and the working conditions around the press. When a machine has been used for other materials or has been idle for several days, it should be thoroughly cleaned. In fact, it is highly desirable to wipe off any surface that comes in contact with the molding powder with a solvent, such as acetone or carbon tetrachloride. On an injection molding press, it is generally easier to remove a cylinder and thoroughly clean it, rather than flush other materials out of the cylinder. This is due to the fact that KEL-F is a high temperature material and, at the temperature required to plasticize this material, other molding compounds will char and burn. After cleaning the cylinder, it should then be washed with carbon tetrachloride, or acetone, to remove any film of grease or other organic material.

You may wonder why all this care and cleanliness is necessary in the handling of KEL-F molding powder. The reason is that, at the high temperatures necessary for molding KEL-F, any foreign matter of an organic nature deposited on or in the KEL-F is decomposed producing brown stains, streaks or dirt marks in the molded parts.

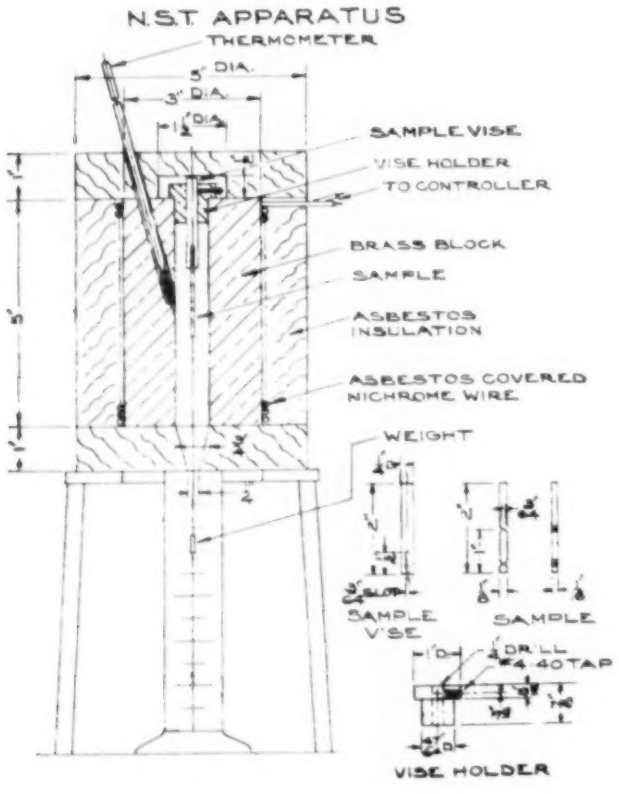

Figure 4. No-strength test apparatus

INJECTION MOLDING:

As this KEL-F polymer is a true thermoplastic, it can be molded in almost any injection press of current manufacture. However, there are several minor changes that are recommended to produce a more efficient operation. Some of these changes are important for other materials but they are more important for KEL-F because of the higher plasticizing temperature and the narrower ranges between plasticization and degradation.

In discussing desired changes and modifications to present molding presses, one of the first items is the instruments used to control the injection cylinder and nozzle temperature. The proportioning type of temperature controller, that has been adequately checked for accuracy, is a practical necessity. The indicated temperatures should not vary more than plus or minus 5° during the injection molding process. The nozzle should be separately heated and controlled with the heat source as close to the end of the nozzle as possible. Most commercial machines presently on the market have a maximum injection pressure of 20,000 p.s.i. As KEL-F, at its plasticizing temperature has a high viscosity, injection pressures as high as possible are desirable, such as up to 40,000 p.s.i. The thermal conductivity of this polymer is very low. Therefore, a cylinder designed to heat the material in the thinnest practical layer is desirable. Also, good contact between the torpedo and cylinder or an internally heated torpedo, in order to heat the material from both sides, is helpful.

The nozzle should have a reverse taper at the tip so that when the sprue is pulled, a small section of KEL-F is removed with the sprue, which will tend to eliminate "cold slugs." It is also preferred that the nozzle be separately heated so as to maintain the nozzle at a temperature above the average temperature of the polymer in the cylinder. Both the nozzle and the cylinder assembly should be designed so that there are no undercuts or pockets for material to hang up and degrade.

Since the rate of degradation of this polymer is a time-temperature function, control of the molding cycle is a most important function. The most important time is that of the overall cycle. This timer should time from the close of the mold to the close of the mold. This overall cycle timer takes the human element variation out of the molding operation and therefore, a change of cycle is not required when a shift or personnel change is made. It is known that a variation in cycle will vary the temperature of the material in the injection cylinder and as we stated previously, we want the material temperature to be held to the smallest possible variation.

In the injection molding process for all thermoplastic materials, as the plasticized material leaves the nozzle and enters the sprue bushing, it starts to cool to a solid state. As it moves from the sprue bushing through the runners and gates and thence into the cavity, it continues to get colder. During the flow of plastic through the sprue, runner and gates, the material next to the metal surface of the mold will solidify first and provide insulation for the center core through which the plastic continues to flow. This produces a skinning effect, that is, the center of the plastic will remain semi-fluid and keep moving under the injection molding pressure, while the outside layer remains fixed. The higher the viscosity of a plastic at its plasticizing temperature, the higher the mold temperature required to allow the flow of plastic from the nozzle to the cavity. A higher mold temperature will tend to reduce the thickness of this skin or eliminate it entirely on heavy cross-sections.

In general, design of injection molds for KEL-F parts are similar to mold designs for other materials. Sprues, runners and gates should be as large as possible commensurate with the design of the particular part that will be molded. This is to provide as large as possible cross sectional area for the material to flow. They should also be as short as possible, that is, the sprues as short as possible, the runner as short as possible and the gate as short as possible. All corners should have generous radii applied to them. The object of these design factors being to move the material into the cavity as fast as possible. Injection molds should be provided with methods of heating to a temperature of 300-350°F. The practical temperature will be as hot as possible, within this range, and still be able to remove parts from the mold. If the mold is electrically heated, suitable controllers should be provided. In the case of heating with steam or a liquid medium, suitable gauges are provided. If a two-plate mold is used, then two zones of heat should be provided and, if a three-plate mold is used, three zones of heat should be provided. All metal surfaces which come in contact with the material should be chrome plated or made from a high grade, stainless steel. This includes the sprue bushing, runner, gates and the cavities themselves. In addition, it is generally good practice to insulate the mold base from the press platens with a material such as transite or asbestos.

In most all injection molding processes, a sprue and runner will be obtained for each "shot" of the molding press. With most thermoplastic material, the sprue and runner can be re-used either "as is" at the press or by regranulating and mixing with virgin material. KEL-F can be handled in the same way except care must be taken to avoid contamination and degraded materials. It is generally advisable to re-use the KEL-F sprue and runner individually and not allow them to accumulate for it is difficult to keep them dirt free.

We have mentioned degradation of KEL-F polymer. Briefly, degradation, accomplished both thermally and mechanically, is a reduction in the length of the polymer chain and hence a reduction of molecular weight and viscosity. This, of course, results in lowered NST value and lowers the resistance of the polymer to high temperature uses.

COMPRESSION MOLDING:

Any part that is possible to mold can be compression molded using KEL-F. The simplest of these parts, such as flat sheets, gaskets and "O" rings, can be molded by using positive type molds, or, in the case of flat sheets and gaskets, between thin metal plates or aluminum foil with stops to give the correct thickness. These type parts can be molded using either a high or low density molding powder and can be preformed to a desired shape, using preform equipment.

Again, it might be well to mention that cleanliness is very important in the fabrication of good parts. Preform machines and dies should be thoroughly cleaned prior to use and not be operated adjacent to preform machines used on other compression type of materials. The powder should be weighed on clean scales and containers used in transferring materials should be glass, plastic or metal but in no case should cardboard, wooden or paper containers be used.

In the manufacture of thin flat sheets, powder, either high or low density, preformed or bulk, is placed between thin metal plates between heated platens of a press, the platens being controlled at a temperature of 520°F. In no case should the temperature go above 550°F. or degradation will occur very rapidly. The temperature should be maintained until the polymer is plasticized and the exact temperature of molding will depend upon the NST of the polymer. Much below 480°F., plasticizing will not take place and the part will have little or no strength. The time required to heat and cool sheet material will vary somewhat with different equipment in different molders' plants. As an example, a disc 1 16" thick x 4" in diameter will take approximately 3 minutes to bring up to temperature and about 2 to 3 minutes to cool. However, by quenching this in cold water, it can be removed from between the plates almost immediately. If a mold is used to manufacture flat sheets, cooling of the mold should be effected under pressure, preferably at a pressure about the initial compacting pressure.

A disc ¼" thick and approximately 30" in diameter will take approximately 1 hour to heat and approximately ½ hour to cool between cold press platens. Other plastic

Figure 5. Electrical insulator. Molded by Fluoro Plastics, Inc., for RCA.

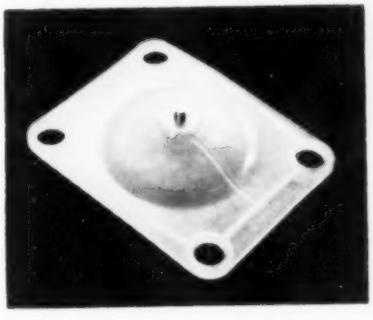

Figure 6. Valve diaphragm. Molded by Molding Corp. of America

Figure 7. Relay spider. Molded by General Electric Co.

parts, such as chemical laboratory ware (beakers, funnels, etc.), pump bodies, valve diaphragms, valve seats and other parts that are too heavy in cross section to be economically molded by conventional injection equipment, can be compression molded using flash or landed type molds. Heating and cooling cycles will again depend on the individual molder's equipment. However, cycles at a temperature of 500°F. will range from 2 to 5 minutes for a 1/16" thick x 4" valve diaphragm, weighing approximately 30 to 60 grams to 1-½ to 2 hours for a 1-½" x 6" insulator weighing 1-½ to 2 pounds. These cycles are based on heating and cooling the article in the mold and preheating of preforms or powder will help cut cycles and is highly recommended for providing a thorough heating of the material.

A variation of straight compression molding is the technique of using a relatively thin, high heat conducting material such as brass or aluminum for fabricating of the cavity and then heating the cavity and molding powder to temperatures in an oven or other suitable piece of equipment. The cavity and plasticized powder is then transferred to a chase then can be cooled. Transfer or plunger molding can also be used, keeping the pot and transfer ram at the plasticizing temperature and only heating and cooling the force and cavity.

Compression and transfer molds should be made from a high grade, stainless steel or chrome plated steel or possibly chrome plated beryllium copper.

Referring again to figures 5 through 9, we can discuss some of the actual molding conditions that were used in the manufacture of these parts.

The insulator, weighing approximately 1-½ pounds, shown in Fig. 5, was molded by Fluoro Plastics, Inc., of Philadelphia, Pennsylvania, in a single cavity compression mold. The overall cycle was approximately 1 hour, which included 40 minutes to heat the material, 20 minutes to cool. The mold temperature was adjusted to 520° F. This molding arrangement was experimental and it is believed that the cycle could be cut approximately in half on a production basis.

Fig. 6 shows a valve diaphragm, weighing approximately ¼ pound and 4" x 5" x ⅛" thick, molded by Molding Corporation of America, Providence, Rhode Island, using plasticized KEL-F in a fully positive compression mold. A temperature of 480-500°F. and an overall cycle of approximately 15 minutes were used. This included 7 minutes to bring the die to temperature, 5 minutes to allow the material to heat and 3 minutes for cooling.

TABLE II

PART TOLERANCES

Nominal Thickness Inches	Tolerance Inches
0.00 - 0.500	plus or minus .0[illegible]
0.500 - 1.00	plus or minus .0[illegible]
1.00 - 2.00	plus or minus .0[illegible]

MOLD SHRINKAGE

Nominal Thickness Inches	Shrinkage Inches/inch
0.00 - 0.250	.005 - .00[illegible]
0.250 - 0.500	.005 - .010
0.500 - 1.00	.010 - .01[illegible]

Fig. 7 is a relay "spider" weighing 2 grams, molded by the General Electric Company in Taunton, Massachusetts, using a 2-oz. Reed-Prentice and a pressure of 34,000 p.s.i. The cylinder temperature was 525°F., the nozzle at 560°F. and an overall cycle of 38 seconds was used. One interesting point is that these parts were molded in a die made for nylon with a gate diameter of .030".

The drum plugs shown in Fig. 8 were injection molded by the American Flange Co. in Linden, New Jersey, on a 2-oz. Watson-Stillman press, using 20,000 p.s.i. For the small plug, weighing 11 grams, the cylinder temperature was set at 520°F. and an overall cycle of 69 seconds used. For the large plug, weighing 51 grams, the cylinder was set at 500°F. and an overall cycle of 2 minutes, 51 seconds, used. Shorter cycles were attempted, however, the KEL-F could not be fully plasticized in less time with this size press.

Fig. 9 shows an electronic tuner molded by Fluoro Plastics, Inc. in Philadelphia, Pennsylvania, and it is believed to be the largest molded piece of KEL-F, weighing approximately 5½ pounds. This was compression molded and the overall cycle was approximately 3 hours. This allowed approximately 2 hours to bring to temperature and 1 hour to cool. The mold temperature was adjusted to 510°F.

On these applications, in general the time cycle of

Figure 8. Drum plugs. Molded by American Flange Co., for drums containing fuming nitric acid.

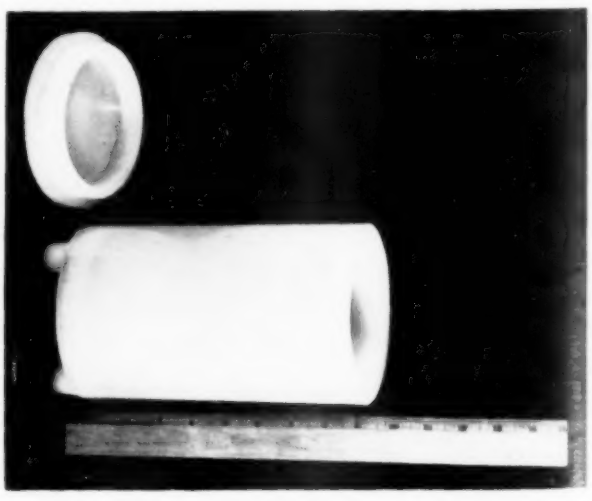

Figure 9. Electronic tuner. Molded by Fluoro Plastics, Inc. →

mold ... will also depend on the NST of the polymer in addition to mold design and size of the part.

Table II shows the part tolerances and mold shrinkage that can be expected in the design and molding of KEL-F parts. These values can be varied by an individual molder's processing techniques, therefore, some deviation from these values can be expected.

In conclusion, it might be well to review a few of the major points necessary for successful molding of KEL-F.

GENERAL

1. Cleanliness of material, machine and working conditions are essential to prevent the introduction of contaminating elements.
2. Cycles should be uniform and well controlled.
3. Stainless or chrome plated steel should be used on any metal surface in contact with the material.

INJECTION MOLDING

1. The injection cylinder design should provide thin cross sections of flowing KEL-F for better conductivity and to avoid material degradation.
2. Die temperature should be as high as possible, 300-350°F., commensurate with ability to remove parts from the mold.
3. Temperature controllers should be of the proportioning type and adequately checked for accuracy.
4. Sprues and runner should be kept free of grease and all other contaminants and reused immediately.
5. Machine feed should be accurate and uniform.
6. Injection pressures to 40,000 p.s.i. are desirable.

COMPRESSION MOLDING

1. Molds should be heated to a temperature of 500°F. and cooled under pressure.
2. Material should be thoroughly plasticized before cooling.
3. Deep draw molds should be vented to prevent air entrapment.
4. Part should be quick quenched for greater clarity.

With these points acomplished, any molder should be able to mold parts using KEL-F successfully.

Electrostatic Properties

(Continued from page 30)

filters made of polyethylene in suitable form will remove wind-borne particles of sand (Figure 5) and pollen grains 25 microns and larger in size. This has been demonstrated in tests on railroad Diesel locomotives and car air conditioning systems and also in the homes of people suffering from dust allergies. ([35])

Thus the inherent electrostatic properties of some plastics, which are normally considered undesirable and may be a hazard, can be employed for a useful purpose if properly applied.

Acknowledgement

The authors wish to thank Joyce Bates and Leora Straka of the Goodyear Research Library for their assistance in searching the literature for references used in this paper.

REFERENCES

1a. A. O. Austin, Monthly Weather Review, July 1931, page 259
1. Francis B. Silsbee, Static Electricity, Circular C438, National Bureau of Standards, U S Department of Commerce.
2. M. S. Pennell, Neutralization of Static Electricity, Paper Trade Journal, April 13, 1950, page 33.
3. F. L. Hoxie, Fire Hazards and Static Electricity in Rubber Factories, Rubber Age **10**, 90-91 (1921).
4. E. E. Turkington, Static Electricity as a Fire Cause, Quart. Natl. Fire Protect. Assoc., **28**, 16-25 (1934)
5. Beyersdorfer, Koll. Zeit., **33**,-101-7 (1923)
6. P. G. Guest, V. W. Sikora and Bernard Lewis, Static Electricity in Hospital Operating Suites, U. S. Bureau of Mines, Report 4833.
7. Power Transm. **8**, 655 (1940); Ann. Report Prog. Rubber Technol. **4**, 89 (1940).
8. Robin Beach, Elect. Eng. **60**, 202 (1941).
9. Accumulation of Static Electricity in Tires, Gummi Zeitung 44, 2591 (1930).
10. T. R. Dawson and B. D. Porritt, R.A.E.R.M., England, 1935, page 431.
11. India Rubber World **103**, 49-50 (1941).
12. J. W. Liska and E. E. Hanson, Ind. Eng. Chem. **34**, 618-24 (1942).
13. S. M. Caldwell, N. E. Handel and G. L. Benson, Ind. Eng. Chem. (News Ed) **19**, 1139-41 (1941).
14. Davis and Blake, Chemistry and Technology of Rubber, Reinhold, 1937, pp. 588-90.
15. H. E. Davis, Trans. I.R.I. **20**, 128-34 (1944).
16. Robin Beach, Rubber Age **58**, 453-60 (1946).
17. W. F. Cooper, Trans. I.R.I. **23**, 26-8 (1947).
18. A. A. Bachhaus, Am. Dyestuff Rept. **16**, 645-6, 660-1 (1927).
19. D. Bulgin, Trans. I.R.I. **23**, 35-40 (1947).
20. I. R. Sperberg, G. E. Popp, and C. C. Biard, Rubber Age **67**, 561-4 (1950).
21. F. H. Cotton, Trans. I.R.I. **6**, 487-515 (1931).
22. W. F. Busse, Ind. Eng. Chem. **24**, 104-6 (1932).
23. P. C. Woodland and E. E. Ziegler, Modern Plastics, May 1951, P. 102.
24. H. H. Hull, J. Appl. Physics **20**, 1157 (1949).
25. P. E. Shaw, Proc. Roy Soc. **94A**, 16 (1917).
26. Deodhar, Indian Assoc. Cult. Sci., **9**, 210 (1926).
27. G. W. Graham, Nature **168**, 871 (1951).
28. Holfeld, Kastner Arch. Naturl. **2**, 205 (1824).
29. F. G. Cottrell, Ind. Eng. Chem. **3**, 542 (1911).
30. Rudge, Phil. Mag. **25**, 481 (1913).
31. Drinker and Hatch. Industrial Dust. McGraw-Hill Book Co. N. Y. 1936.
32. Lodge, Soc. Chem. Ind. **5**, 572 (1886).
33. J. Alexander, Colloid Chemistry, Vol. I, pp 407-10, Chemical Catalog Co., N. Y. 1926.
34. Angewandte Chemie, B, **20**, 335-36 (1948).
35. W. T. Van Orman and H. A. Endres, ASHVE Journal Section, Heating, Piping and Air Conditioning, January 1952, pp 157-63.

A.S.T.M. Meetings

Committee D-20 on Plastics, Pocono Manor, Pa., March 23-25.
Committee D-9 on Electrical Insulating Materials, Pocono Manor, Pa., March 25-27.

Committee D-14 on Adhesives, Cincinnati, Ohio (Netherland-Plaza) April 9-10.

Committee C-19 on Structural Sandwich Construction, Chance Vought Aircraft, Dallas, Texas, April.

1953 ASTM Annual meeting, Atlantic City, N. J., Chalfonte-Haddon Hall, June 29-July 3.

1953
SPE Prize Paper Contest
RULES

NO AGE LIMITATIONS

Open to Non-Members and Members Alike

1. The subject must be in the field of plastics technology but can cover any phase of materials, processes, applications, products, manufacturing equipment, testing equipment, or the like.

2. Papers must be original. Papers previously published in any form will not be considered.

3. Papers which merely review the previously published literature will be considered only when such a study is directed toward a useful and new objective.

4. Five copies of the paper shall be submitted, of which one shall be an original.

5. All drawings and/or all figures should be done in India ink on tracing paper or a good grade of white paper. All photographs and figures should be clearly and adequately labeled. Such material should not be clipped from papers, magazines, or advertising brochures and pasted on sheets of paper or pasted on sheets of typewritten matter. All illustrations should be mounted on separate sheets.

6. Full credit for all material quoted from other sources must be given.

7. Length of paper should not be over 5000 words.

8. All papers submitted become the exclusive property of the Society of Plastics Engineers, Inc.

9. Papers must be submitted to the nearest local SPE section not later than November 1.

10. Entries from foreign countries, or from non-members who are uncertain of the address of the nearest SPE section, should be submitted directly to "Prize Paper Contest," Society of Plastics Engineers, 513 Security Bank Building, Athens, Ohio.

Papers will be judged on the basis of their value to the industry or to the engineering profession in the field of plastics technology. They will also be judged on the skill with which the subject is analyzed and presented.

AROUND THE WORLD

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AUSTRALIA

AUSTRALIAN PLASTICS

Vol. 8, No. 87, October 1952

Abstracter: Albert Lightbody

POLYVINYL ACETATE EMULSIONS (A. E. Lever)

Polyvinyl acetate emulsions, now being used as coatings and adhesives, find many uses such as in book bindings, in making non-woven fabrics, in water-based paint and in leather finishing. The effect of the use of plasticizers, resins, pigments and anti-foaming agents are discussed as well as tests to determine the usefulness of the emulsions.

TRI TOLYL AND TRI XYLENYL PHOSPHATE PLASTICIZERS IN THE PLASTICS INDUSTRY (W. S. Penn)

As meta-para cresol to mak Tri-Tolyl phosphate has not been sufficiently available to meet the demand, Tri-Xylenyl phosphate has been introduced as a substitute. A comparison of the two plasticizers is made with various resins with emphasis on their use in cellulose acetate, cellulose acetate butyrate, cellulose nitrate and ethyl cellulose.

BRAILLE PRINTING FOR BLIND AIDS (From British Plastics)

An exhibit at the National Institute for the Blind in London has featured a new Braille printing method which eliminates the old method of embossing. This new technique employs perforated stencils through which an urea-formaldehyde based ink can be applied to the paper. This process has been made automatic from the production of the stencils through to the final printing operation.

PLASTICS FOR AUTOMOBILE BODIES (From British Plastics)

The making of glass reinforced plastics automobile bodies and their potentialities are discussed.

SYMPOSIUM OF REINFORCED PLASTICS (From Canadian Plastics)

Selection of the proper applications for reinforced plastics structures is a major problem. Raw materials and the techniques employed, with the characteristics of the reinforced plastics are emphasized. A brilliant future for this type of material is predicted.

SYNTHETIC RESINS FOR THE FOUNDRY (Plastics)

The use of urea-formaldehyde and phenol-formaldehyde resins as binders for sand cores for foundry use is described in some detail.

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FRANCE

INDUSTRIE DES PLASTIQUES MODERNES

Vol. 4, No. 10

Abstracter: Hans Mayer

THE PLASTICS IN THE AUTOMOTIVE INDUSTRY.—

Follow up of story in November issue, dealing with the use of Acetates, Acetate Butyrates, Polystyrene, Polyethylene, etc., in cars, and using U. S. A. applications as examples.

PROGRESS IN THE CANDY INDUSTRY—

This article describes the replacement of metal molds by injection molded polystyrene forms which permit the casting of chocolate shapes without large outside seams.

VISIT TO DUSSELDORF—

Describes the Plastics Exhibition in Dusseldorf and enumerates materials, machinery and appliances on exhibit.

THE EXTRUSION OF FILM AND TUBING FROM ACETATE AND ACETATE BUTRYATE by E. C. Blackard of Tennessee Eastman.

Reprint of the text of the paper presented at the eighth technical congress of the SPE.

"SEMI-TRANSFER" V-50 INJECTION MACHINE BUILT BY A.M.-I.M.—

This machine is different from conventional injection machines by the "Semi-Transfer" type construction of the cylinder. This cylinder has no torpedo, the plasticizing is accomplished by forcing the material from the cylinder through a second chamber of smaller Dia. towards the nozzle. It is claimed that this construction results in higher efficiency (up to 40%) compared to the conventional cylinder setup. The machine described has a capacity of slightly more than two ounces of cellulose acetate per shot and can plasticize approximately 35 lbs. per hour.

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GERMANY

KUNSTSTOFFE

Abstracter: Anne Schwend

A continuation of the abstracts from the October, 1952 issue of Kunstoffe.

AUXILIARIES
Pigments, Dyes, Fillers, Lubricants, Stabilizers, Expanding Agents, Printing Inks
by Dr. Jurgen Koerner

The summary of such a heterogeneous scope as it is presented by the auxiliaries used for the processing of plastics cannot represent more than a general and a universally valid summary. The following topics are dealt with in detail: Dyes, pigments and the dyeing process for the different types of plastics, fillers, lubricants, stabilizers, expanding agents and printing inks.

DISPERSIONS OF PLASTICS
by Dr. Gustav Hagen

To-day high molecules gained by polymerisation as well as by polycondensation and polyaddition are processed in form of dispersions. The stability of dispersions could be essentially improved by variation in the colloido-chemical structure of the dispersions, and dispersions of plastics with specific properties for various fields of application could be developed by suitable selection among the monomeric compositions.

PLASTICIZERS FOR PLASTICS
by Dr. phil. habil. Heinrich Berger

Our ideas on the efficacy of plasticizers have become much clearer by recent research. A standardization of the terms and the continuation of the testing and standardizing methods is of importance. This contribution is a report of the progress and recent development of this work. It contains a table evaluating the properties of various commercial plasticizers.

MOULDING AND TRANSFER MOULDING
by H. Draeger

The most frequently applied transformation methods for thermosetting compounds into shaped articles are moulding and transfer moulding. The design according to the properties of the material, of the cast part, a thoroughly workable moulding compound with constant properties, appropriately constructed moulds as well as a rational and qualified working technique are the conditions for the production of well shaped articles. Each of these factors has decisive importance. An essential improvement in many cases was achieved by the transfer moulding, the advantages of which are described.

PRODUCTION OF LAMINATES
by Dr. G. B. von Hartmann

Recent tendencies of development in the range of laminate production are dealt with. The increasing importance of decoration materials is specially considered.

PROGRESS IN INJECTION MACHINE BUILDING
by Obering. Hans Beck

The main problem of the development of heavy injection machines consists in the proper design of the feed and heating cylinder. A partial solution is the pre-plastification. A combination of screw and plunger machines will probably lead to a lighter design with bigger output.

CASTING AND DIPPING OF PLASTICS UNDER CONSIDERATION OF THE CASTING OF FOILS
by Dr. C. A. Bodenstein and Dr. H. Paul

After various ways of manufacture of plastic foils and the principal fields of application have been discussed, the casting of films is compared with the other procedures of manufacture. The progress achieved and the problems still to be solved, especially with regard to photographic base material to be coated with emulsion, are dealt with. A brief description on cast resins and the immersion of plastic solutions and dispersions follows.

PROGRESS IN SCREW EXTRUDERS AND THEIR APPLICATION
by Obering. Hans Beck

The single screw extruder as all-round machine for various purposes has not yet been invented and neither can it be imagined. The development, therefore, shows special constructions continuous working kneaders and twin screw machines. Screw type extruders now are used for manufacturing granulate and films.

THE PROCESSING OF PLASTICS ON ROLL MILLS AND CALENDERS
by Dr. W. Lampert

The article deals with the design and the supplementary equiment of calenders with respect to the uniformity, the small thickness and an outmost width of plastic films expected by the film manufacturers.

COATING AND LAMINATING
by Dr. Gerhard Beck

In the field of coated and laminated fabrics the PVC pastes possess outstanding technical and economical advantages. The progress of methods is reported here as applied in the covering of nylon and perlon fabrics with the application of final coatings to prevent plasticizer migration, in the search for leathercloth of porous nature „permeable to air"; finally mention is made of the development of specialised plant.

FOAMS AND LIGHT WEIGHT STRUCTURAL MATERIALS
by Dipl.-Ing. Peter Hoppe

In the following article the future possibilities of application for foams are discussed from the engineer's point of view.

WELDING AND SEWING
by Dipl.-Ing. Tankred von Hauteville

The further development of special high-frequency electrodes and other devices as well as measures for curtailing the cooling time in the heat impulse procedure are discussed.

THE DEVELOPMENT IN THE ADHERING AND GLUEING WITH PLASTICS
by Ing. Eugen Bock

An attempt is made to determine the state of development of adhering with plastics in some important spheres for adhesives.

CUTTING OF PLASTICS
by Dipl.-Ing. H. Zickel

In the following article the developments which occur in the turning of laminates, in the sawing and polishing and finally in the cutting of tough non-rigid plastic scraps are discussed.

PROGRESS IN FLAME SPRAYING OF PLASTICS
by Dipl.-Ing. E. Gemmer

The utilization of polyethylene-isobutylene-compounds, of polyamides and ethoxyline resins and eventually of polytetrafluorethylene extended the field of application for flame spraying of plastics. Furthermore progress depends on many technical - manual details.

DYEING OF PLASTICS
by Dr. H. Steinmeyer

The choice of separate types of dyestuff is critically discussed in view of this position. As a further criterion the "leaching out" caused by chalking, bloom, sublimation and blurring is treated. The paragraph on the dyeing procedure is dealing with 'Dry Dyeing' of polystyrene injection moulding compounds.

PRINTING ON PLASTICS
by Dr. Reinhard Buchwald

Printing on plastics is a problem of the development of suitable printing inks and of the selection of the most favourable corresponding printing procedures. Information is given on the nature of the printing inks and on the requirements which must be met and also on modern printing procedures which have been specially developed for plastic working, and are discussed for particularly important fields of application as for instance viscose and PVC foils, Pliofilm, polyethylene and polystyrene.

EMBOSSING
by Dr. P. Dornbusch

The improvements concern controlled and wrinkle-free unwinding and winding up as well as guide of sheetings, the shaping of the rubber counter-roll, the preheating of goods and the cooling. The embossing process can be extended by "filling with paint or spraying the debossed areas and wiping off excess material", whereby the disadvantages of coloured embossing or overdyeing are largely avoided. The number of engravings has been increased by the introduction of the light refracting effect of smallest surface hatchings („Echolux").

METALLIZING OF PLASTICS
by Dr. Richard Springer

To-day there are various ways of metallizing plastics. Another method is the application of metal carbonyl. The results recently achieved by this procedure are treated and the magazines' and patent literature is taken as a basis.

FLAKING
by Dr. Ing. Erich Escales

The electrostatic flaking on suitable adhesive layers which guarantee the adhesion to the base as well as abrasion resistance and water-proofness is a new and diversified working field for plastic products. Complete plants for the permanent flaking of sheets up to 250 cm. of operation width have been developed in addition to improved electrostates.

REPORT OF PROCEEDINGS 1951/52, SPECIAL GROUP "PLASTICS AND CAOUTCHOUC" OF THE GERMAN CHEMICAL SOCIETY (G.D.Ch.).
by Dr. A. Hoechtlen

REPORT OF THE WORK SPECIALIST'S COMMITTEE FOR PLASTICS OF THE GERMAN ENGINEERS SOCIETY (V.D.I.)
by Dipl.-Ing. E. Mollberg

REPORT OF PROCEEDINGS OF THE UNIONS OF GERMAN PHYSICAL ASSOCIATIONS
by Dr. K. Wolf

REPORT OF PROCEEDINGS OF THE SPECIAL STANDARDISING COMMITTEE FOR PLASTICS IN D.N.A.
by Dr. R. Rohm and Dipl.-Ing. G. Ehlers

REPORT OF PROCEEDINGS 1951 OF THE „TECHNICAL ASSOCIATION"

by Dipl.-Ing. E. Mollberg and Dipl.-Ing. E. Romer

It is the main task of the association to guarantee an improvement of quality of the produced moulding compounds and of the parts manufactured therefrom. Standardisation and supervision, which is carried out voluntarily, are especially adapted for this purpose.

REPORT OF PROCEEDINGS OF THE „ARBEITSGEMEINSCHAFT DEUTSCHE KUNSTSTOFF-INDUSTRIE (AKI)"

by Dr. Gunter Suhle

The „Arbeitsgemeinschaft Deutsche Kunsthstoff-Industrie" was founded on 8th February, 1951 by the two associations, the „Verband Kunstestofferzeugende Industrie and verwandte Gebiete e. V. (VKE)" and the „Gesamtverband Kunststoffverarbeitende Industrie e. V. (GKV)" in order to strengthen the activity of the economic and technical associations of the plastics industry and to combine the head-offices of these organisations. The promising progress which had been made by the Arbeitsgemeinschaft shortly after it has been founded up to time of the Plastics Industry meeting in 1951, continued during the second year of its existence and proved very successful. For the first time this report publishes details regarding the above.

HEATING OF MOULDS IN THE PROCESSING OF PLASTICS

by Dipl.Ing. Th. Henne

Moulds are commonly heated by electric resistance heating and with hot water. Finally constructive measures are discussed which are important for the economy and the constant temperature of moulds.

DESIGNING AND MANUFACTURING OF TOILET SEATS BY MOULDING AND INJECTION MOULDING TOOLS

by Obering. Hanns Turnwald

The toilet seat made of phenolic moulding compound is actually cheaper than the injection moulded seat despite requiring longer production time. It is, however, possible that this may change due to the rapid development of injection moulding compounds and injection moulding technique. Therefore an installation and a tool have been developed which allows the application of both the manufacturing procedures at any time.

MANUFACTURE OF SEMI-FINISHED PRODUCTS AND SHAPED PARTS MADE OF ARALDIT-CASTING RESIN B

by Dr.-Ing. Chem. Konrad Meyerhans

First of all it is pointed out which measures must be taken for the processing, shaping and treatment of dies

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DER PLASTVERARBEITER

Vol. 3, No. 11, Nov. 1952

Abstracter: E. C. Bernhardt

RECENT DEVELOPMENTS OF THE BADISCHE ANILIN AND SODA FABRIK IN THE FIELD OF PLASTICS by Dr. F. Stastny

This article gives a comprehensive survey of the new products of the BASF including their application characteristics.

I. **KAURIT and URECOLL-F.** These are Urea-Formaldehyde base adhesives which have recently been improved and are now practically odorless.

II. **POLYACRYLONITRILE.**

III. **DIORID and DIOFAN-D.** Diorid is a polyvinylidene chloride. 50% water dispersions are available under the trade name "Diofan-D" for the production of film and coatings.

IV. **LUVICAN** is a polyvinyl carbazole which has recently become available in a transparent grade. It has a softening point of above 200°C and has outstanding electrical properties.

V. **OPPANOL BA SHEETING.** This is a polyisobutylene which has been especially compounded to herve as a moisture barrier in the construction and road building industry.

V. **CASTING RESIN P1 and P3.** These are unsaturated polyester resins for casting and laminating applications.

VII. **STYROPOR** is a new grade of polystyrene which contains a foaming agent. It is sold either as pellets, as beads, or in block form. The pellets or beads are placed in perforated aluminum molds. Enough polymer is added to fill approximately 1/10 of the cavity. The mold is then placed in hot water (95-100°C). The polystyrene softens and foams at that temperature driving the water out of the mold through the perforations. It is claimed that specific weights of the molded products of 0,03-0.3 are obtained. "Styropor" in block form can be sliced into disks. These disks can be foamed into thick sheets by immersing them in water at 95°C.

VIII. **EMV POWDER 120 FD** is a new powdered polymer from which the consumer makes his own water emulsion by simply adding water, plasticizer, and an alkali.

IX. Review of recent improvements on the standard plastic materials made by the BASF.

HARLON — A NEW SYNTHETIC FIBER

"Harlon" is a polyvinylidene chloride fiber. Very complete data on physical and chemical and aging properties are given.

CONSTRUCTION OF MOLD CAVITIES THROUGH HOBBING—Spies

A general survey of the various steps necessary to prepare a hobbed mold cavity.

SURVEY OF THE 1952 PLASTICS EXHIBITION IN DUSSELDORF

A review listing and describing various exhibits at the exposition.

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GREAT BRITAIN

BRITISH PLASTICS, Dec. 1952

Abstracter: Herbert R. Simonds

EDITORIAL

Changes are taking place in the plastics industry just as they have in medicine in recent years. The effect of pencillin is compared to the impact of polystyrene in plastics.

Cellulose acetate is one of the materials to feel this impact. The experience of U. S. producers is pointed out. In 1946, 83,000,000 lbs. of cellulosic molding powders were produced against 67,000,00 lbs. of polystyrene, a ratio of 5:4. However, by the end of 1951, the ratio was 1:5 in favor of polystyrene.

In light of this approach of "the right material for the job"—which should be axiomatic in plastics—the extensive use of cellulose acetate by a leading British toy manufacturer as described in this issue is significant.

CELLULOSE ACETATE FOR TOY PRODUCTION, Widespread Use by Leading Manufacturer (6 pages illustrated)

What is said to be the largest toy manufacturing organization in the world use cellulose acetate as its principal plastics material. This is the International Model Aircraft, Ltd., the Plastics Division of the Lines Brothers Group of companies.

When choosing a material for making toys, one of the first considerations is the strength and durability of the finished product. Cellulose acetate is a tough material and meets the stringent requirements of toy making. It can be molded into small or large products, can be used for simple or complex shapes and possesses the right amount of resilience.

Another important factor in toy making is color. The Lines Brothers Group places such importance on preproduction and investigation that they employ one-hundred research workers to carry out market research, color testing and humidity experiments. A sculptor is also included on the staff.

The article describes the produc-

tion of various toys such as boats, tractors, dolls, etc.

LAMINATES IN THE HOLLERITH TABULATING MACHINE (2 pages illustrated)

Hollerith punch card accounting machines have become part of the general British administrative background. Parts of the Hollerith tabulating machine made of plastics include the following:—

1) The binary unit control drum employed for adding pence, etc., is built up from Tufnol laminate rings,

2) The gear wheels in the upper counter are in Bakelite laminate,

3) The mass of small electrical components, many of which incorporate laminate materials,

4) Two grades of Bakelite laminate are used for the control panels which are the brains of the machine,

5) The alphabetical control unit has a laminate drum and brush-holder,

6) Both commutator and board are fabricated from laminate materials,

7) A laminate control panel,

8) Feed cams, molded in phenolic, have laminate insulating plates.

PLASTICS APPLICATIONS (4 pages illustrated)

The items pictured this month include:—a textile bobbin, desk accessories, a switch fuse control unit, a sink tray with a screen-like framework, fishing rods, a babies' bottle in polythene, and an insulating jacket for hot or cold liquid storage made up of a ¾-in. layer of fiberglass with a canvas backing and a glossy polyvinyl chloride exterior.

FAST-CYCLING MACHINE STEPS UP PRODUCTION, Novel Type of Injection-Cylinder Assembly Gives 1,200 Shots An Hour (3 pages illustrated)

A maximum rate of 1200 cycles an hour has been obtained on a new type of machine using a 5-gram shot. This machine is said to be an entirely new type of injection-cylinder assembly, patented in Britain and the U. S.

This fast cycling machine appears to offer definite advantages over previous types. Sectional cuts illustrate the operation which consists briefly of a main injection plunger around which is a prefilling ring plunger. This ring is withdrawn to receive the new charge of material. It is then forced forward forcing the molding material around the end of the main injection plunger. With this action the main cylinder travels back away from the nozzle, then the prefilling ring travels forward, compressing the material after which it is ready for its forward injection stroke. The manufacturers, Dowding & Doll, Ltd. claim that the extremely fast cycle of their new machine means a reduction of tooling costs in addition to other savings. The machine is designed to be fully automatic, requiring only one operator for a battery of machines.

TYPICAL PHYSICAL PROPERTIES OF VARIOUS POLYSTYRENES

ASTM Test	Units	Polystyrene	Medium-impact polystyrene	High-impact polystyrene
Tensile strength	lb. sq. in.	5700-9500	5500-6500	4500-5500
Elongation	@	1.5	10	12-30
Modulus of elasticity x 10^{-5}	—	450-550	400-425	325-375
Izod impact strength ½-in. bar	ft. lbs. per inch notch	0.25-0.45	0.4-0.6	0.7-1.5
Heat distortion temperature	°F	175-204	170-195	160-195
Water absorption	% 24 hr.	0.05	0.05-0.1	0.06-0.25
Hardness, Rockwell	M scale	75-80	65-70	5-55

PHYSICAL PROPERTIES OF IMPACT POLYSTYRENES (1 page)

The newer impact polystyrenes are widening the range of applications for which this material is used.

It is estimated that by 1962 the American plastics industry will be using 600,000,000 pounds of styrene monomer. The impact materials are mixtures of styrene monomer and a plasticizer. The plasticizers are copolymers derived from butadiene and styrene. Typical physical properties of high impact polystyrenes compared with other types of polystyrenes are shown in the table above.

SYNTHETIC RESINS IN THE FOUNDRY by D. N. Buttrey (6 pages illustrated)

Some years ago synthetic resins found a natural application in sand core binding. Since then many new applications in the field have been developed and the article describes some of them.

Dielectric heating for instance has greatly reduced drying times of resin-bonded sand cores. A polyester resin is expected to find application in certain types of core-boxes, replacing more expensive metal ones.

Accelerated liquid resins available for spraying on to the mold surface to give a hard skin to the mold at normal temperatures.

The main advantages claimed for urea resins for core-binding are as follows:—

1) Low initial cost of the urea resins.

2) Short baking time of cores.

3) Rapid breakdown of cores during casting.

4) Absence of finning on castings, and reduction of scrap caused by knock-out difficulties.

Disadvantages of these same resins are given as follows:—

1) Stickiness of cores in the green state.

2) Objectionable odor during core-making, drying and especially during casting.

3) Low green strength.

The urea resin box formula for sand core formulation is given as follows:—

	General formulation (parts by weight)
Sand (silica)	100
Urea resin	1-2
Cereal binder	1-2
Water	2
Paraffin, mineral oil or core oil	¼

The use of phenolic resins in core-binding is more recent than that of the urea resins, but there has been an upsurge in the use of the phenolics, especially in iron foundries. Some of the advantages for phenolics are as follows:

1) Low initial cost of phenolic resin binders.

2) Short baking time of cores.

3) Efficient breakdown of cores during casting.

4) Low gas evolution and absence of objectionable fumes during casting.

The disadvantages are:—

1) Stickiness of cores in the green state.

2) Low green strength.

A typical core sand formulation employing phenolic resin is as follows:—

	General formulation (parts in weight)
Sand	100
Phenolic resin	1-2
Cereal binder	1-2
Water	2-5
Paraffin	¼

A recent development has been the use of polyester resin as a core drier. A typical formulation is as follows:—

Nuron polyester resin
25 parts by weight
Dry silica sand
74 parts by weight
Chopped glass fiber
1 part by weight

Details of the shell-molding process are given. Briefly, the sand phenolic resin mixture is allowed to fall on to a hot pattern surface. The pattern then is transferred to an oven and heated until the resin sets. The shell is then lifted from the pattern. Two such shells are clamped together to form a mold ready for casting. For small castings, it is possible to cast into the unbacked shell.

COMPARATIVE PROPERTIES OF ALKYD AND OTHER MATERIALS

Property	Alkyd mineral filler	Alkyd organic filler	Urea pulp filler	Melamine mineral filler	Phenolic Type GX woodflour filler
Tensile strength p.s.i.	3,000-4,000	5,000-6,000	6,000-8,000	5,000-6,000	7,000-9,000
Specific gravity	1.82-2.2	1.35-1.50	1.45-1.50	1.79-1.9	1.35-1.40
Water absorption, mgm	70-100	100-200	150-250	70-100	110-150
Tracking resistance	good	good	good	good	limited
Blister temperature, °C	200-250	200-250	140-160	180-200	150-170
Volume resistivity, ohm-cm	10^{14}	10^{13}-10^{14}	10^{10}-10^{11}	10^{13}-10^{14}	10^{10}-10^{12}
Color possibilities	limited	good	excellent	limited	limited
Electric strength, 90°C volts mil	200-300	100-150	50-100	100-200	50-150

COMPOSITION AND PROPERTIES OF ALKYD MOLDING MATERIALS by **J. H. Bennitt** ($1\frac{1}{2}$ pages)

This article is a study of just how far the alkyd thermosetting molding materials are affecting the phenolic and amino types.

In comparison with phenolic resins, the alkyd resins are lighter in color and resistant to darkening in light. In respect to color they approach the effects obtained from urea resins. The alkyds have not the dimensional stability of phenolic moldings but are better in this respect than comparable urea or melamine moldings. The comparison of properties are given in the following table:—

LETTERS TO THE EDITOR

Under this section Mr. G. F. Bassett of Ashdowns Ltd. takes exception to a statement made in the November issue, to the effect that no glass-based laminates, particularly those employing silicone resins, are available in England having electrical properties equivalent to those in the U.S.

Mr. Bassett states that his company manufactures glass fiber laminates with water absorption values below 0.1% and insulation resistance of above 1,000 meghoms.

LACQUERING POLYSTYRENE MOLDINGS (2 pages illustrated)

Polystyrene cannot stand the high temperatures required by bake-type lacquers. Oven drying however, to speed the drying process is a fairly normal practice. The problem is to select the material that has adhesion, color, minimum drying time, resistance to abrasion and low cost.

TRADE NOTES AND NEWS

Exports of plastics in October jumped to 3,315 tons as against 2,568 tons in September.

A polymer known as nylon soluble polymer type CA is soluble in alcohol water mixtures and is now being produced in small quantities. It is said to be important as a textile finishing agent. A grade known as Calaton CA has been developed for this purpose.

PLASTICS IN ENGINEERING (2 pages illustrated)

This gives a condensed version of a lecture to the Plastics Institute given in November by J. Gordon of the Plastics Department, Royal Aircraft Establishment.

Mr. Gordon suggested that the potentialities of plastics in engineering may bring about another fundamental change in aircraft manufacturing technic.

Suggestions for the Future: Mr. Gordon states that prospects are "dazzling." For instance there is the possibility of a soft piezo-electric material. Such a material might expand or contract by a small amount by applying an electrical potential. This would change the whole approach to structural engineering, according to Mr. Gordon.

★

PLASTICS, November 1952

Abstracter: Alfred T. Rexer

NEW EXPANDED PLASTICS:

A new form of expanded plastic material which is completely different from the chemically expanded type is illustrated and described. The basic principle consists of cutting a large number of "staggered" slits in the plastic sheet which is subjected to stretching and, since there is some elasticity, retention of the desired expanded shape is attained by the use of a special molding technique under heat. Various applications are described.

P.V.C. SHEET SHOWS ITS MEDALS

A description of a public display of p.v.c. sheet and goods made from it to indicate how much the p.v.c. resin makers, the producers of sheet, and the manufacturers of goods from the sheet have progressed and collaborated during the past few years. All the goods displayed conformed to the new British Standard Specifications and all such goods will eventually bear, either on the wrapping or package, an easily recognized certification mark. Before a licence is granted for using a mark, the British Standards Institution has to satisfy itself that full control is being exercised by the manufacturer to ensure adherence to the standard. The article is well illustrated.

PLASTICS IN THE SERVICE OF MAN

A pictorial review of high-quality units molded or otherwise fabricated in Great Britain.

GLASS REINFORCED PLASTICS IN THE AIRCRAFT INDUSTRY: G. C. Hulbert

An extensive article by a member of the Bristol Aeorplane Co., Ltd., Development Engineers Dept. It covers the raw materials available, the resins and glass reinforcement; their properties when laminated; types of application; design considerations; manufacturing methods in the aircraft industry; and a description of some structures and their method of manufacture. In general, glass reinforced plastics materials are very efficient electrically, being particularly transparent to radar frequencies. Their fatigue resistance is very good, as is also their ability to withstand impact. When so damaged, the affected area is very local and is amenable to simple and speedy repair. Finally, they offer complete freedom from normal corrosion hazards associated with conventional metallic materials. One of their most important weaknesses is their low erosion resistance, particularly when applied to the external surfaces of high-speed aircraft.

★

PLASTICS INST. TRANS., LONDON

Vol. 20, No. 42 (1952)

Abstracter: Harriman H. Dash

THE PROPERTIES AND APPLICATIONS OF SYNTHETIC WATER-SOLUBLE POLYMERS.

F. P. Grimshaw

Synthetic water-soluble polymers, primarily cellulosic derivatives, have become commercially available and are widely employed as thickening,

film-forming, and stabilizing agents to replace the natural materials (starch, gelatin, agar, etc.). The preparation and properties of the following types are described:

(1.) Cellulose Derivatives

Ethers (Methyl, ethyl, carboxymethyl, hydroxyethyl) — The solubility depends upon the degree of etherification (Substitution) per glucose residue (D.S.) which may vary from 0 to 3. Water-solubility for the various ethers fall within the following D.S. ranges:

Hydroxyethyl	1.5-2.6
Methyl	1.3-2.5
Ethyl	0.8-1.3
Carboxymethyl	0.3-0.8

Mixed ethers are also produced by reacting soda cellulose with two or more etherifying agents. Methyl-ethyl-cellulose was found to be the most outstanding emulsifier, useful for most types of oils over a wide pH range.

Esters (sodium salts of sulphate, succinate, phthalate, etc.).

(2) Starch derivatives (esters and ethers).

Starch consists of two fractions, amylose and amylopectin. The former is a straight-chain, high molecular weight polymer, and it is this fraction which is used for esters and ether formation. Pyridine is employed as a catalyst in ester formation to prevent degradation. Ethers are prepared by treatment of the starch with the alkyl halide in the presence of alkali.

(3) Vinyl Polymers. (Polyvinyl alcohol, pyrrolidine, methyl ether, and copolymers.)

(4) Polyacrylates. (Polyacrylic and methacrylic acids).

(5) Polyethylene (Polyethylenimine, polyethylene glycols).

(6) Glycol Borates.

Application of the above polymers are discussed in detail for the following materials and processes:

Textiles (sizing, finishing, printing, spinning), Paper (Beater and tub sizing, coatings,), Leather, Paint Adhesives, Foods and Pharmaceuticals, etc.

A very comprehensive bibliography is provided by the author.

FIBER-FORMING POLYMERS
R. J. W. Reynolds

Synthetic fibres are logically regarded as a branch of plastics. A very brief historical sketch traces the early development of synthetic fibres from naturally occuring polymers (cellulosics). The natural fibres were found to be macromolecules of a partly crystalline structure.

Following these discoveries, the work of Carothers led to the synthesis of fibre-forming polymeric macromolecules. Orientation of these produced high tensile strength fibres. This was followed by the commercial application of polyamides (Nylon), the success of which assured the development of many other synthetic fibres (polyethylene, polyethane, polyacrylonitrile, polyvinyl chlorides, etc.).

High molecular weight, long chain macromolecules are required for fibre forming. Such chains must possess sufficient symmetry to allow orderly packing (alignment) and strong (polar) interchain bonds. Stiffness in the synthetic fibre is a function of the repeating unit in the polymer chain. Aliphatic polymers with a CH repeating unit (e.g. polyethylene, polyvinyl chloride) are generally more flexible than polymers containing a p-phenylene grouping (e.g. terephthalates). Synthetic fibres may be formed from addition or condensation polymers. The properties of several fibres produced by melt or solution spinning are described. The manufacturing processes are briefly discussed with emphasis on the starting materials for their syntheses. The future of "synthetics" is compared with that of natural fibres. The former are finding extended applications for which the natural fibres are unsatisfactory.

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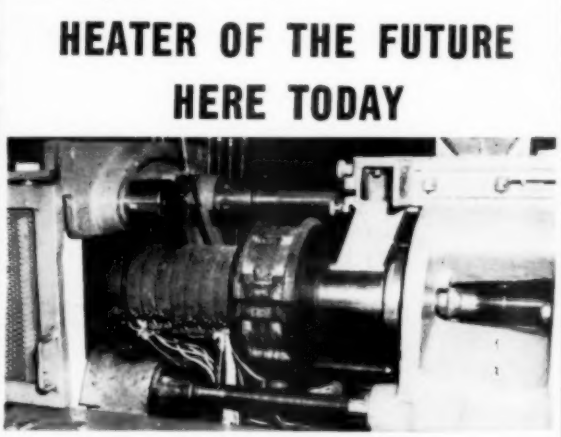

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PLASTICA, Vol. 5, No. 11

Abstracter: W. P. ter Horst

POLYELECTROLYTES

Dr. J. J. Hermans

Polyelectrolytes differ from other polymers in that their molecules carry an electric charge and they differ from other electrolytes because of the fact that their ionic charges are much larger than those of ordinary ions.

In this article attention is focused upon the polyelectrolytes consisting of linear molecules. The shape of the molecules in its dependence on the composition of the electrolytic composition of the solvent is considered. Viscosity, non-Newtonean behaviour, the titration curve, the osmotic pressure of solutions and the swelling of gels are considered with the aid of general considerations on the influence of electrolytes on the shape of the polyelectrolytic molecules.

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MEXICAN RUBBER AND PLASTICS

Vol. XII, No. 82, December 1952

Abstracter: John B. Ballard

A STUDY OF THE MIGRATION OF PLASTICIZERS IN VINYL COMPOUNDS—James R. Gentry

Description and discussion of a method of checking the diffusion of plasticizers used by Goodall-Sanford, Inc.

Vol. XII No. 81

SARNIA, CENTER OF THE PETROCHEMICAL INDUSTRY OF CANADA—E. R. Rowzee

The history and operations of the petrochemical industry in and near Sarnia, Ont.

★

UNITED STATES

National Bureau of Standards—Research Paper #2192

Abstracter: Gerald Eisner

COMPRESSIBILITY OF NATURAL AND SYNTHETIC HIGH POLYMERS AT HIGH PRESSURES by Charles E. Weir

In this article, compression data ($-\Delta V/V$) are reported between 1,000 and 10,000 atmospheres for the following materials: dry cellulose, polyvinylidene chloride (Saran), polyethylene, polymonochlorotrifluroethylene (Kel-F), polytetrafluoroethylene (Teflon), a polyester (Selectron 5003), and raw rubbers, Hycar OR25, Hycar OR15, Neoprene, and Thiokol ST. All compression curves are smooth except for Teflon which shows a transition at 5,500 atmospheres. Empirical equations are developed in this report for the compression of each of the above materials.

The compressibilities

$$-\frac{1}{V}\cdot\frac{dV}{dP}$$

of each material is developed and comparative graphs are shown. One interesting point found by the experimenters was that the compressibilities of all materials tested appeared to reach a minimum at approximately 10,000 atmospheres.

★

JOURNAL OF POLYMER SCIENCE

Vol. 9, No. 2, pages 133-156

RATES OF THERMAL DEGRADATION OF POLYSTYRENE AND POLYETHYLENE IN A VACUUM by Samuel L. Madorsky

When heated in a vacuum at 325° to 375°C., polystyrene yields mainly the monomer and some dimer, trimer, tetramer, etc., indicating that the breaks in the molecular chains occur largely at the ends. Polyethylene, under similar conditions, but at a somewhat higher temperature, yields fragments of an average molecular weight of about 700, indicating that the molecular chains break, mostly at random positions. A study was made of rates of thermal degradation of these two polymers by measuring rates of loss of weight of samples by means of a very sensitive tungsten spring balance enclosed in a vacuum. The samples were limited to 5-6 mg. in order to avoid spattering during degradation. Rate curves plotted against per cent loss of weight by volatilization indicate that in the case of polystyrene the process is intermediate between a zero and first order reaction, while in the case of polyethylene, the process approximates a first order reaction. Activation energies were calculated on the basis of rates of degradation at various temperatures. The values thus obtained for polystyrene and polyethylene are 58 and 68 kilocalories, respectively.

Arnkurt Moves

Arnkurt Associate Engineers have moved to larger quarters and expanded their facilities. Their services include industrial engineering, product design, model making and electroformed spray masks. They are at 31 E. 27th St., New York City.

Temperature Control And Press Heating

(Continued from page 35)

the heat accumulation capacity of high temperature liquids.

By using high temperature liquids, such as water, it is possible to accumulate the heat required for the short peak load in an accumulator and reduce the load on the boiler to a fraction of that required for steam heating.

HOW DOES AN ACCUMULATOR WORK?

Figure 8 shows an accumulator installed in a press heating system using high temperature water. One pump continuously circulates water between the steam heater and the accumulator, raising the temperature in the accumulator. Another pump circulates water through the press, using three-way valves to control the temperature of the fluid delivered to the press, varying the amount of cool and hot water drawn from the cooler and the accumulator respectively.

A comparison is shown in **Figure 9** of the loads on the boiler, using steam and using water, with and without water accumulator. The steam consumption is seen to reach almost 17 tons per hour. When using high temperature water for the same heating cycle the peak is reduced to about 13.6 tons per hour, and the load is spread somewhat into the period of time when the press is not absorbing heat. This illustrates the heat accumulator effect of high temperature liquid heating systems. Now let us note the effect of an accumulator. The steam consumption never exceeds 6 tons per hour. A substantial portion of the boiler load occurs during the non-heating part of the cycle. The boiler required for the system using an accumulator would need to be only **one third** the size of the boiler needed for the steam heated press. Or, to put it another way, it would be possible to triple the number of presses served by a given boiler installation by converting from steam to high temperature liquids using such an accumulator.

It is later than you think. Let us be progressive—let us utilize this modern era heating system. We can do this without hesitation. The early dream castle of high temperature liquid heating for calenders, presses, and molds, has now become earthborne, solidly supported by the available engineering designs and technical experience accumulated during the last 25 years. The inadequacies and difficulties experienced in the first designs have been eliminated. This knowledge is now at your disposal. You all can enjoy the great advantages of this advanced heating technique.

SECTION NEWS

Edited by
Stanley Bindman
Jamison Plastic Corp.
71 E. Sunrise Highway
Freeport, New York.

VACUUM FORMING PANEL AT CONNECTICUT

Properties and applications discussed for Styrene

David Mersey

There is an old saying, 'if you don't like New England weather, just wait a minute.' Time, January 9, 1953; place, Bridgeport (or anywheres in these parts); weather, cold, rain, wind, sleet, snow; result, sixteen members at the first '53 meeting.

The sixteen straggled in until it was decided to hold the meeting. The subject was, 'Vacuum Forming,' and was ably presented by Mr. Bowman Stratton of the Auto-Vac Company of Fairfield, Conn., and Mr. Stanton Smith of Dow Chemical Co.

Mr. Stratton presented the vacuum forming process as an outgrowth of his wartime experiences with the forming of relief maps from preprinted plastic sheets. These maps met the most rigid cartographer's tolerances. He is now manufacturing vacuum forming equipment at the Auto-Vac Company at Fairfield, Conn.

Vacuum forming may be used with all thermoplastic materials, plasticised or not. The two most important factors in this process, are: fast vacuum, and uniform, fast heat. However, some special effects may be produced by using differential instead of uniform heat. Briefly, in this technique, the heated sheet is drawn against a male or female mold. Such molds are low in cost, and may be made of plaster; metal sprayed over a rigid frame; cast resins as the epoxies; aluminum, or magnesium.

Usually the sheet is printed before forming, the print being done by any of the more common processes, such as, screen, litho, or spraying. There is very little (if any) distortion between the printed sheet and the finished formed product.

This process opens new fields in packaging and displays. In the latter field, many third dimensional effects can be produced in a single operation. In the field of displays, certain economies might be realized by printing the flat sheet before forming, instead of attempting to produce the same result on the irregular surface after the sheet has been formed. Among the specimens on display, were, relief maps; third dimensional signs; containers; nail-head and corrugated patterns on plasticized vinyl film; trays; dishes, mannequin parts, etc.

Thus far, the process has been limited to the use of thin sections, from, 0.000" to 0.800".

Scrap is a factor in this process, and it was suggested that, where there is a continuous extrusion-forming process, the scrap might be reground and reused as soon as it is generated. Another suggestion was that it be reused as injection molding material.

Mr. Smith, in his portion of the program, stressed: low tool cost; low capital investment; diversity of size applications per machine; the opportunity in producing a profit or short runs which would be precluded in injection molding; economies in materials by using thinner sections than are possible with injection molding, especially where thin sections are adequate.

Dow produces #475 styrene in uniform thickness, in colors white and gray. It was presented as a lower cost material than other thermoplastics, such as, vinyls, acetate, or butyrate. At the present time only these two colors are available; however, more are due in the near future. This sheet has the same characteristics as other styrene compounds or alloys; such as, limitation to opaque colors; the same solvent reactions; and limitations on outdoor applications.

Some recommended applications are: in refrigeration, television, air conditioning; signs and displays; kitchen utensils.

Buffalo Meeting Hears Plasticizing Machines Described

R. H. Rushmer

The monthly meeting of the Buffalo Section of the Society of Plastics Engineers was held on Friday evening December 19, 1952, at the Elks Club, Delaware Avenue, Buffalo.

Mr. R. E. Davis of the Plastics Machinery Division of the Hydraulic Press Manufacturing Company was the guest speaker. Mr. Davis presented a paper on the subject, "Pre-Plasticizers" telling the story of the development of pre-plasticizing types of injection molding machines.

The pre-plasticizing principle was employed by H.P.M. as long as 20 years before the development of the spreader which has been used in conventional machines for many years.

Pre-plasticizing is defined as the condition wherein granulated or powdered molding material is completely plasticized before coming in contact with the injection plunger which forces the material into the mold.

Pre-plasticizing offers the following advantages:

1. Increase in plasticizing capacity on a given size machine.
2. Increase in the shot capacity of the machine.
3. Production of relatively strain-free parts.
4. Reduction of weight per part.
5. Reduction of temperature in heating chamber.
6. More effective utilization of the mold clamping force.
7. Reduced distortion.
8. Improved ease of part releases from the mold.
9. Improved color dispersion.
10. Improved surface finish and color.

The meeting was preceded by a Smorgasbord at the Elks Club for members and guests.

Rochester Takes Flight To The Future

E. W. Goral

The December meeting of the Rochester Section of the S.P.E. was held at the Powers Hotel Dining Room, 34 Main Street West. Mr. Clarence F. Van Epps, President, welcomed back Mr. Carmen Giannotta who attended the meeting during his recent visit to Rochester. Mr. Giannotta was Secretary of the Rochester Section prior to his transfer to the Newark Section in June 1952.

The membership was entertained by a showing of the full-color 16 millimeter sound film "Flight To The Future" made available through the courtesy of the Bakelite Company.

NEWARK TALK ON LARGE INJECTION MOLDS

Ex-prexy Ed Rowan given gold watch

E. G. Ackerman

The Newark Section started off the New Year with a bang Jan. 14th as 230 members and guests met at the Military Park Hotel, Newark, N. J. and heard from an outstanding panel on large injection molding. The Newark Section played host to members of the New York Section as well as many guests from as far away as Chicago.

Ed Rowan, Dillon-Beck Manufacturing Company, opened the meeting by welcoming members and guests to the first meeting of 1953. Ed then introduced the newly elected officers from the New York Section as follows: President, Saul Blitz, Noma Electric Company; Vice-President, Harold Schwartz, Empire Brush Company; Secretary-Treasurer, Bill Lewio, Dusal Tool Company; National Director, Stanley Binman, Jamison Plastics Corporation.

At this time, Ed Rowan introduced Newark's new President, Jack Pecktal, Eastman Chemical Products, Inc., who in turn presented Newark's new officers and committee chairmen as follows: Vice-President, Kirby Preston, Celluplastics Corporation; Secretary-Treasurer, Bill Willert, Frank W. Egan Company; Director, Don Bicken, Orangeburg Manufacturing Company; Director, Winnie Trautweiler, Newark Die; Director, Milton Sanders, Bloomfield Molding; Program Chairman, Ed Saules, Detroit Mold Engineering; Membership Chairman, Bill Preston, Koppers Company; Credentials Committee, Bob Hoehn, Mack Molding Company; House Committee Co-Chairmen, Dr. Irving Goldrich, Irvington Varnish and Insulator Company and Al Herring, Naugatuck Chemical Company; Publicity Chairman and SPE Reporter, Ed Ackerman, Riedl and Freed, Inc.; Professional Activities Committee Chairman, Wayne Schragg, Gering Products, Corp.; Educational Committee Chairman, Peter Simmons, Dow Chemical Company; and Technical Societies Representative, Milton Sanders, Bloomfield Molding Company.

President Pecktal, on behalf of Newark Section, expressed their sincere appreciation to past President Ed Rowan for his untiring efforts for the Newark Section and his continued efforts in behalf of the National Society and presented Ed a gold watch as a token of this appreciation.

Jack then turned the meeting over to the man responsible for such a large attendance, Don Biklen, Newark's Program Chairman. Don introduced Bob Hoehn, Mack Molding Company, who acted as moderator for the panel composed of R. W. Barber, Director of Advanced Engineering, Panelyte Div., St. Regis Paper Company, Trenton, N. J.; R. W. Van Sickle, Manager Heat Fabrication Section, Dow Chemical Company, Midland, Michigan, Ernie Csaszar, Chief Engineer, Eagle Tool and Machine Company, Newark, N. J.; Russ Powell, Manager Plastics Div., The Hydraulic Press Manufacturing Co., Mt. Gilead, Ohio; A. J. Dematteo, Chief Engineer, The Watson-Stillman Company, Roselle, N. J.

Mr. Barber opened the meeting with an introductory talk reviewing the status of large injection molding. Each panel member described the work being done in his particular phase pointing out the numerous problems encountered in making and using the large molds.

Mammoth molds weighing 8 to 10 tons are being made today. Because the cavities are so large, they are not set into a frame. Prehardened steels are used which have a hardness between 34 and 37 Rockwell "C." This degree of hardness causes the toolmaker no end of grief with his machining. The handling of these molds is quite difficult and proper provisions must be made in the tool shop as well as the mold shop. In designing molds when the mammoth injection presses were first coming out, not enough rigidity was given to the mold and as a result, appreciable deflections took place.

Sufficient support must be maintained between the base plate and cavity plate. This gives the knockout plate a Swiss cheese effect and consequently, the k.o. plate must be increased in rigidity. Anchoring the mold in the horizontal injection press causes a problem due to the weight. Ball bearings are contained in the guide pin bushings to prevent seizing.

Preplasticizing and weighed feeding play an important role in injection molding. Parts that are molded with preplasticizing equipment will sometimes weigh about 5 per cent less than those parts molded on conventional equipment. The audience learned from the panel that it was not feasible to consider molding many small parts in a large mold. An example was cited where a 400 cavity spoon mold was made.

There is a great potential for large moldings but even with the present sizes of large injection machines made today, numerous problems have to be solved by the toolmaker and molder for they are the fellows who have to worry about the mold.

Meetings—Don Biklen promises us another good meeting on March 11th. Quent White of Stokes Machine will talk on "Automatic Molding." Sam Greenwood, also of Stokes, will discuss "Twin Screw Extruding."

Personals — Rowland Frankenpohl formerly with Newark Die is now associated with Interstate Mold Corp. of Hillside. . . . Best of everything to our secretary Ruth Helm who was married December 6th. . . . Contributions to this column are welcome. Just send a postcard to E. G. Ackerman, 269 Broadway, Paterson, New Jersey.

See you at the next meeting.

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Dear Friends:

It was a pleasure to meet so many of you in Boston and to know that you do look each month to see what we have to say here. We have mentioned a very few prize jobs in the past few months and realize that perhaps you would like to know some of our secrets. Well, some things can be told, but of course those do not include what new products we are working on for our clients. We will tell you a few secrets in the months to come and will try to throw in a sketch now and then. The main secret of good design work (or any kind) is "Don't stop work until all details have been cared for." Thanks for a pleasant time in Boston and I think John LaBelle and his host of helpers did a fine job. See you on this page next month.

Yours for Better Living with Plastics
Wayne I. Pribble

"WHAT'S IN A MIRACLE" TALK ON SYNTHETIC FIBERS ROUSES PHILADELPHIA INTEREST

Adolph J. Kissileff

The Ladies got top billing at Philly's Annual Ladies' Night.

Editha Austin, Fashions Director of Virginia-Carolina Chemical Corp. treated the gals to a show they are not likely to forget for some time. Miss Austin, former Fashions Editor of Vogue Magazine led our glamour-packed meeting through the doors to the future of the Textile Industry with her scintillating subject, "What's In a Miracle." The ladies were completely overwhelmed by her thrilling word picture of what is in store for them in synthetic fibres. Not only were they given an opportunity to hear the amazing details of the story itself, but were also able to actually see a demonstration of some of these wonder fabrics already processed into articles of wearing apparel.

After Miss Austin's address, she very graciously answered question after question regarding details of the fabrics in actual use, such as cleaning, laundering and other maintenance factors, as well as the proper selection of weaves for the various seasons. Even the men, normally willing to leave such activities to the "little woman," were carried into the questioning period because of the intense interest manifested by the ladies.

For the first time in this area, it is believed that members will find a greatly reduced resentment toward the "I-won't-be-home-to-dinner-Plastics-Meeting-tonight" phone calls they make once a month.

Jack Stokes, local SPI President, and toastmaster of the evening, was joined by a fellow member of the Stokes Trenton firm in the top brass category, when George Koch, retiring SPE Philly President presented Charley Davis as the new head of 1953. Koch also announced the other SPE Officials for 1953 as follows: Henry Darlington of A. H. Wirz, Inc., Vice President; Edward Derowski of Penn Plastics, Secretary; James E. Rex, Plastic Center, Treasurer. Dick Bishop, Research Engineer of Socony-Vacuum Company was elected to the office of National Director, replacing National President William Bracken, whose term was completed as of the end of the year.

Announcement of the subject for January's meeting was made by Jack Stokes. "Trouble Free Molding of Nylon" will be presented by a panel of duPont representatives.

Philadelphia Section, by continued cooperation of SPI in combining our monthly meetings, continues to move forward. Evidence of increased interest on the part of the buying public is found in the ever growing popularity, and constantly wider usage of plastic items as shown by greater sales in both stores and industry around the entire area. From all indications, the Philadelphia Section will continue to be instrumental in improving the position of the Plastics Industry here. 1953 activities of the local Plastic organizations include more and better Public Relations which will no doubt increase this interest.

SLUSH MOLDING OF PLASTISOLS IS TOPIC AT RHODE ISLAND AND S. E. MASS. SECTION

John R. Sloane

The first dinner meeting of 1953 of the Rhode Island and South Eastern Massachusetts Section under new President Bertram M. Brown was held at Wayland Manor Hotel, Providence, R. I. on January 8th. The meeting was well attended, with two new members and several guests present.

The featured speaker was Mr. E. M. Hayden, Vice-President of The Stanley Chemical Co., East Berlin, Conn., on the subject of "Slush Molding of Plastisols." Mr. Hayden defined a Plastisol, less frequently called a Vinyl "Paste," as a dispersion of Vinyl resin in non-aqueous, non-volatile liquid which does not dissolve the resin at ordinary temperatures.

When this liquid dispersion is heated to a temperature of 300 deg. to 400 deg., the vinyl resin dissolves in the liquid portion of the dispersion, changing phase from a dispersion to a solution. This fusion process solidifies the plastisol, changing it so that when cool it is a tough, rubbery material characterized by outstanding abrasion resistance, electrical properties, and resistance to many acids, alkalies and corrosive chemicals.

Slush molding of plastisols received its first real start when its applicability for producing doll parts was realized. Arms, legs and heads for dolls, slush molded from plastisols were found superior to those made from latex in color retention, feel and washability. It was found that much better detail could be obtained as well. By the slush molding process many items impossible to manufacture in rubber, could be economically produced.

Molds are very cheaply produced. First an artist familiar with slush molding prepares a drawing of the desired item. A model is then made which is transferred into wax. To prepare the first mold, the wax model is silver plated, then a nickel coat is electroformed over this. A final plating of copper is applied until the total wall thickness is about 1/16 inch thick. After the final plating operation is complete, the wax is melted from the mold and the silver is removed. The manufacture of duplicate molds is accomplished by simply molding vinyl parts and repeating the plating procedure, using the vinyl piece instead of wax.

Mr. Hayden described, and illustrated with slides, the three general systems of slush molding which might be called the "One-pour," "Two-pour" and "Rotational" methods. An interesting factor in Slush Molding is the low cost of molds. Molds for the open type of Slush Molding cost roughly $50 to $150 for the first mold, and subsequent molds about $20 to $50 each. Molds of the closed type are usually more expensive. The conveyorized systems for the "one" and "two" pour methods can be made without too great expense, even when large production is required.

There are several basic reasons for the growing interest in Slush Molding by Vinyl Plastisols. 1. Small capitol investment to get started. 2. Faithful duplication of detail in the parts. 3. Quality and durability of the finished articles. 4. Speed of production. 5. Color range practically unlimited.

Space does not permit a more detailed report on Mr. Hayden's talk, although it would make interesting reading. There is no question but that Slush Molding offers tremendous possibilities in the production of certain items, with moderate investment of capitol. Many concerns will find it to their advantage to further investigate this newer method of producing plastic products.

Ed Drinkwater, Arnold Babble and George deBeaumont discuss printed circuits

PRINTED CIRCUITS ELECTRIFY SOUTH CAL.

Robert Whann

A panel of experts discussed "Printed Circuits" at the January meeting of the Southern California Section. The panel discussion was designed, not to define printed circuits, but to present the major considerations from the viewpoints of an electronics designer, a material supplier and a fabricator. Mr. Ed Drinkwater—electronics designer of Consolidated Engineering, Mr. George de Beaumont—material supplier of Synthane Corp. and Mr. Arnold Babbe—fabricator of Technical Reproductions, were the panel members. The keen interest in the subject was indicated by the attendance of 135 members and guests at the meeting.

The discussion was presented by having a series of pre-arranged questions posed by the moderator to the panel for answer.

Committee Chairmen Announced At New York

A. M. Merrill

New York Section committee chairmen for 1953 were announced by president Saul Blitz, Noma Electric Corp., as follows: membership, Richard M. Thews, Monsanto Chemical Co. (to July 1), and Murray J. Beck, Leaf Plastics, Inc. (after July 1); program, Irving I. Rubin, Robinson Plastics Corp. (to July 1), and Herbert J. Weber, Rotuba Extruders, Inc. (after July 1); house, Guy Martinelli, Sylvan Plastics, Inc.; credentials, George B. Baron, Ideal Plastics Corp.; prizes and favors, Carl W. Virgin, Naugatuck Chemical Division, United States Rubber Co.; employment, Arthur L. Gewertz, manufacturers representative; mailing, G. Palmer Humphrey, R. C. Molding Co.; education, Harold H. Schwartz, Empire Brushes, Inc.; and publicity, Arthur M. Merrill, "India Rubber World."

Six new members have been added by the Section since October, as follows: John R. Cummings, technical service representative, Borden Co., Chemical Division; Julius Fass, partner, Master Tool & Die Co., Herbert L. Lawrence, time study engineer, Ideal Novelty & Toy Corp.; Daniel Lifschitz, components engineer, Arma Corp. Peter W. Potecha, technical director, Imperial Crown Toy Corp.; and Walter A. Stadtler, technical service laboratory manager, International Business Machines Corp. (Poughkeepsie office.)

On the non-technical side, congratulations were extended to Mr. and Mrs. Saul Blitz on the birth of their daughter, Hedda Sue, on December 1.

The New York Section were guests of the Newark Section at a joint dinner meeting on January 14.

Christmas Party Pleases Miami Valley

John L. Russell

A very successful Christmas Program was held on Friday, December 5 at the Hartwell Country Club, in Hartwell, O. There was dancing, games, corsages for the ladies and the evening closed with an excellent buffet supper. The committee is to be congratulated for its work in planning this excellent party.

Ralph Backscheider, our new Vice-President, is a hard worker and booster for S.P.E. but informed the writer that he wanted credit only for work actually performed. Carl Weber, rather than Ralph, served as Chairman of the Christmas Party on December 5. Thanks, Ralph, for calling our error and apologies to Carl. As this is being written at the year's close, we send along an ardent wish to each and every SPE member for a very successful year in 1953.

Detroit Selects 1953 Officers And Directors

Emil Gazdick

On December 16, 1952, the Detroit Section of the Society of Plastics Engineers, held their annual Christmas party at the Park-Shelton Hotel.

Don Hoffman, as program chairman, arranged this most successful affair.

The highlight of the evening was the serving of a smorgasbord dinner, arranged by Nils Karlholm, catering manager of the Park-Shelton. The smorgasbord tables were accented with a chiseled ice emblem of the Society, and were truly an impressive sight.

After dinner, there was a drawing for numerous beautiful gifts donated by the plastic concerns represented by the membership and their suppliers.

The party was attended by one-hundred seventy members and guests.

Last year's Elections have brought three new directors to the Detroit Section Board of Directors. They are as follows: Roy Smith—Yardley Plastics Co., Harry Husted—Swedish Crucible Steel Co., Carl Whitlock—C. H. Whitlock Associates.

These men will serve for a term of three years in accordance with the Constitution and By-Laws of the national S.P.E.

The remaining members of the Detroit Board of Directors are: William De Galen—Koppers Corporation, Erik Erikson—Detroit Plastics Products, Emil Gazdick — Evans-Winter-Hebb, Inc., Michael Herzina—Mold-A-Matic Company, Fred Berdan—E. I. duPont de Nemours & Co., Inc.

On January 9 ,1953, the Board of Directors elected the following officers for 1953: President, William De Galen; Vice President, Erik Erikson; Secretary, Michael Herzina, and Treasurer, Harry Husted.

Flek Corporation To Specialize In KEL-F

Formation of the Flek Corporation, a California firm which will specialize in the molding of KEL-F plastic parts, was announced today by Robert L. Cummer, President. The new plant is located at 2252 East 37th Street in Vernon. Jay W. De Dapper is General Manager.

According to Mr. De Dapper, the company has just completed the installation of modern equipment for injection, transfer, compression and extrusion molding. Although the company is now equipped to mold all industrial plastics, it will specialize in molding KEL-F—a unique material produced by The M. W. Kellogg Company.

Miami Valley Gives Plastics TV Show

John L. Russell

Miami Valley Section, SPE, recently was featured in one of a series of 16 Television Program titled "BLUEPRINTS FOR TOMORROW," which is sponsored by the Dayton Technical Societies Council (DATEC), an organization of all the Technical Societies in Dayton and the Miami Valley.

Each week (Sunday afternoon) one of the Technical Societies participates in the 30 minute TV Program over Station WLW-D. The Producer of the series was the Kirchner, Helton and Collett, Inc., Advertising Agency of Dayton, and the script was worked up by our Miami Valley SPE Board of Directors. The actual participants on the program were Byron Nelson, of the National Cash Register Co., Dayton, O. and John Brierley, Buckeye Molding Co., Miamisburg, O.

The purpose of these programs is to elevate the status of the Engineer and to highlight some of his accomplishments.

From all reports the SPE Plastics presentation was exceptionally well received in Dayton and the Miami Valley.

We feel that while, perhaps, this type of endeavor may not be original with Dayton and Miami Valley Section, it most assuredly possesses great merit and from President Merle Nelson on down we are convinced that our representatives Byron Nelson and John Brierley did a splendid job. By all standards it definitely was an accomplishment for Miami Valley Section.

Mr. Nelson has served the Society as Vice-President and Mr. Brierley, as Treasurer, during their terms as Directors.

Southeastern Ohio Elects 1953 Officers

Paul M. Smith

The December meeting of the Southeastern Ohio Section was held at the City Restaurant, Byesville, O., Dec. 12 with a dinner at 6:30 P.M.

Meeting was called to order by the President and ballots were distributed to the members present.

John Verburg was elected President; Paul Smith, Vice President; John Chomicz, Secretary; Fred Burkhart, Treasurer; Frank Bailey, Paul Brill and Fred Burkhart, Directors.

The program chairman Mr. J. W. Knight discussed the available speakers for the coming year.

Mr. Geo. Edwards offer was accepted to have the February meeting at Frazeysburg.

Meeting was closed by the President and a tour thru the Fabri-Form plant was enjoyed by everyone. Points of interest at the plant were the vacuum forming of sheet plastic, welding plastic, fabrication and model work and forming molds by metal spray over a form such as plaster.

Golden Gate Hears About San Francisco in the '50's

V. C. Rollins

At the Annual Christmas Meeting of the Society of Plastics Engineers, which was held this year at the El Jardin Restaurant in San Francisco, Mr. Vern Rollins of Monsanto Chemical Company presented the members, their wives and guests the sp[illegible] titled "San Francisco in the [illegible]."

Mr. Rollins pointed out w[illegible] San Francisco was like in 1852 as [illegible] well as 1952 and compared the gr[illegible] historical events that had occ[illegible]ed in the past century. He traced San Francisco's development curve [illegible] his speech as well as methods of [illegible]ravel, the mecodiums of dress, livi[illegible] quarters, transportation, commun[illegible]ations and other significant events. Since the season was Christmas, he traced the family of 1852 as contrasted with the family of 1952.

He then presented the film entitled "The DuPont Story."

THE *Injection* MOLDERSCOPE

By A. R. Morse

President, Injection Molder's Supply Co.

1952

1952 saw a steady but slow healthy growth in preplasticizers. HPM continued to expand its activities in that field, and pretty soon HPM, Watson, Reed and Impco will all have a machine in the 12-20 oz. range with preplasticizers. What we need now is a survey to determine just what kind of work can be done on these machines. Will they replace the conventional single cylinder machine entirely in the range above 16 oz.? Are they a cure-all for the seesaw that always balances clamping capacity against plasticizing capacity and gives a molder a headache because an 8 oz. job must be run on a 20 oz. machine?

Last year also saw a sudden spectacular rise in weigh feeding. The idea simmered all year till fall, then whoosh, everybody rushed to jump on the weigh feed bandwagon. Harold Schwartz of Empire Brush (who has been the real godfather of Impco's growing success in the injection field) tells of completely eliminating strain in a molded part by using exact weight feed, and Dan McFaddan of Michigan Plastics Products tells of eliminating a costly variation in piece weight on an oversize shot on a 32 oz. Reed. We must give Gordon Thayer credit for weigh feeding's success and to the Glengarry people in Bay Shore Long Island for perfecting such a neat machine to accomplish it!

STYRENE CO-POLYMERS

Our remarks on styrene copolymers caused a healthy stir. A trade paper is gleefully rushing through 20 case histories to prove I am a liar; and those people who read the **SPE Journal** just to gloat over our vagaries thought they had me for sure this time. However, I stand by my premise. The injection molder will do well to remember that the revolutionary new combinations of styrene mold more like acrylic than like styrene. These different molding characteristics derive largely from the improved properties of these materials, and have a de-rating effect that can be troublesome in various ways until more experience is gained with them. If the de-rating is not seen in ounces of capacity, then it does occur in pounds per hour, or in lengthened cycle, or in part quality. In figuring jobs with these materials I repeat my previous warning—do not expect them to mold like styrene at styrene cycles, with styrene gates, and with styrene tolerances. Heating cylinders of special design can be used to overcome the need for lengthening the cycle when using these heat resistant materials. Furthermore, as the materials are improved, (indeed I believe they will be improved to the point where they are almost thermosetting in nature) machines are going to have to be improved to keep up with them. It's amazing how my remarks were twisted, and reactions were worst from people who had not even read them! Talk about the chemistry of co-polymers—you should see it at work in the steam above the Injection Molderscope Co'umn!

THE INJECTION MOLDERSCOPE

Loud cries of "Throttle that guy Morse!" were drowned at a recent national council meeting, and by a slim margin they decided we were a healthy enough influence to let us live a little longer. So the one small uncensored voice in the injection industry will continue to bring you one man's view-point of our progress. However, I myself can't keep up the same pace. Snipers will have to draw a finer bead. Editor Day says I can cut to one column! A good sign this—it means your SPE Journal is growing in editorial content—and in dignity.

Elastomeric Vinyls

(Continued from page 15)

extruded goods are ample proof of the fact that the screw machine does a very good plasticizing job. The extruder has the further advantage in that the screw moves all of the material forward and out of the hot barrel so that there is little opportunity for a material to hang up and decompose. Therefore, a combination of a screw-type plasticizing machine with an injection molding unit would be the ideal machine for injection molding of vinyls.

Such a machine employing the Hendry Screw Pre-Plasticizing principle has been on the market for several years. One of these machines has been running for over a year, molding vinyl distributor cap nipples. On this job the cycle was shorter than a conventional machine, and the gloss and surface was better. Figures 5 and 6 show a general view and a view of the plasticizing section of this type of machine.

Pre-plasticizing by means of an extruder offers a great many advantages. First of all, the screw does a much better plasticizing job than can be obtained by pushing material through a heated cylinder containing a spreader. There is ample experimental evidence to confirm this fact. The thoroughly plasticized material produces molded parts with better surface finish and gloss, and with freedom from cold spots and splash marks.

The screw pre-plasticizing machine can be operated at much lower temperatures than conventional machines. Typical vinyl compounds can be molded at 250° extrusion chamber and injection chamber wall temperatures. Frictional heat does bring the material temperature up to approximately 320°F. at which point it is in an ideal state to mold. Since the metal walls with which the material comes in contact are well below the temperature at which decomposition is appreciable, the danger of burning material is practically eliminated. Also, the self-cleaning design of the screw, and better streamlining of the injection chamber through the elimination of the spreader preclude the possibility of material remaining in contact with the hot metal walls long enough to start burning.

One of the big advantages of the screw-type, pre-plasticizing machine lies in its increased plasticizing capacity. It has usually been found that the molding time is established by the time required to plasticize sufficient material for the mold charge rather than by cooling time in the mold.

By way of example in running a 9 ounce shot on a conventional 12 ounce injection machine, the overall molding cycle was 135 seconds on the average. The parts were sufficiently cold to be removed from the mold in 30 seconds, yet the cycle could not be reduced because after a few shots the material was too cold to mold. Nor could the temperature be increased to compensate for shorter cycles without starting to get thermal decomposition. Under these particular conditions the plasticizing rate of this 12 ounce machine was calculated to be only 18 pounds of vinyl material per hour. In contrast, the plasticizing rate of one of the 16 ounce, screw-type, pre-plasticizing machines with a 2-$^1/_2$ inch screw **on the same material** was found to be 60 pounds per hour, an increase of 233% for an increase of only 33% in rated machine capacity. Without a doubt further increases in plasticizing capacity can be obtained under optimum conditions, since similar material is often extruded from a 2-$^1/_2$ inch extruder at a rate of more than 100 pounds per hour. Therefore, the overall molding cycles can be greatly shortened due to the increased plasticizing or melting capacity of the machine.

The screw pre-plasticizing unit has a still further advantage over conventional machines for molding soft vinyls. The screw is so designed as to give the maximum in compounding action. Therefore, it is unnecessary to use compounded material for molding. By definition, compounded material here refers to granules of compound produced by fluxing the resin, plasticizer, stabilizer, color, etc., either in a heated Banbury-type mixer or on a two-roll mill; sheeting, then dicing or granulating. In contrast to this compounded or granular material, the screw-type machine will mold material prepared by mixing all the ingredients in a ribbon-type mixer until a dry, free-flowing powder results. Sufficient heat is supplied to the jacket of the blender to cause the resin particles to absorb the plasticizer so that the resultant powder is similar in appearance and feel to granulated sugar. The ability of the screw-type machine to mold pre-blends results in a number of advantages. First of these is a large reduction in material costs. The Banburying, milling, and granulating operations are all eliminated. Savings in material cost have been estimated at from 8 to 11 cents per pound in favor of the pre-blend manufactured in the molder's plant over the same granular formulation purchased from the various plastics materials suppliers. In addition, the pre-blend, having a much lesser heat history, should be able to withstand more additional processing or end use heat than granular material. The use of pre-blends will also add flexibility to the molder's operations in inventory reductions, and ready availability of colors or special compounds.

Additional advantages of the pre-plasticizing, screw-type injection machine are ease in changing colors and reduction in down time for cleaning out heating cylinders. Also, the size and location of mold gates is considerably less critical since it is not necessary to depend on the gate for the final plasticizing action.

There are also some disadvantages in connection with using the screw pre-plasticizing type of machine. This machine is more expensive, but not unreasonably so when consideration is taken of the fact that it is in reality two machines; an injection machine and an extruder. There are temperature control problems arising from the frictional heat generated in the screw but these can be solved by application of extrusion techniques on similar materials. As with any type of pre-plasticizing machine where the injection plunger pushes on hot, soft material, there is some leakage of material back along the plunger. This leakage can be brought under control if plunger and cylinder liner are constructed from materials which can be run at relatively close clearance without scoring.

SUMMARY

The elastomeric vinyl plastics offer both a fertile field for new product development and at the same time a number of production molding problems to the custom molder. These materials have properties which will permit them to replace rubber in many applications, bringing to those applications plus factors of better appearance, better aging, and lower costs.

In the present state of development the soft vinyls are difficult to mold in conventional type injection machines. Most of the difficulties can be traced directly to the poor plasticizing action of the heating cylinder on these materials. The factors of poor thermal stability and low thermal conductivity of the materials account for the difficulty in obtaining good plasticizing action. The use of frictional heat generated by forcing the material through small nozzle openings and through pin-point

(Please turn to page 59)

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Furfuryl Alcohol Resins

(Continued from page 11)

retains in solution or in intimate mixture with it a small, but nevertheless significant amount of the acidic catalyst employed in its preparation.

The new resin intermediate is permanently thermoplastic by itself. It allows, therefore, for the preparation also of a molding powder with unlimited storage life. Thus, the intermediate may be blended with part of the filler, and the catalyst with the remainder of the filler. The resulting two powders are then blended at some convenient time before use. Maleic anhydride is an excellent catalyst for this application, but other catalysts may be used. A liquid catalyst or a catalyst solution is preferably absorbed on a suitable absorbent, such as carbon, before blending with the filler, or the absorbent may constitute the filler.

The reaction to produce the FA resin intermediate, in the presence of activated alumina, may be stopped at any point. It is possible, therefore, to obtain liquid intermediates of any desired viscosity, and free from monomeric FA. The conventional liquid FA resin intermediates, used as coatings, cements, adhesives, casting resins, and impregnants, are generally obtained by diluting a more vicous intermediate with monomeric FA. The presence of monomeric FA is undesirable, both because the amount of water split out during the final cure is increased, and because some of the monomeric FA is lost by evaporation during the final cure. Both of these occurrences may cause porosity in the final product.

A liquid intermediate is also suitable for reaction with other components to get a modified end-product. The patent literature gives numerous suggestions as to such compounds (phenols, formaldehyde, thiocyanates, and so on). Since the new method of producing intermediates described above gives a simple means of following the progress of the condensation (by measuring the amount of water split out), the new method makes practical the addition of such modifying agents, at any desired point in the reaction.

ADVANTAGES OF THE GAMMA ALUMINA PROCESS OF PRODUCING FA RESIN INTERMEDIATES

The Gamma alumina process described in the above offers several advantages, some of which have already been pointed out.

The economic advantages are obvious. In the conventional process of producing FA resin intermediates, a solvent is added to moderate the reaction, the intermediate formed must be washed and (or) neutralized to inactivate the acidic catalyst employed, and finally the intermediate must be dried (even if the above moderating solvent is water, it must still be separated from the intermediate). All these steps are eliminated in the new gamma alumina process.

In addition to being cheaper to produce, the gamma alumina process intermediate is superior to the conventional intermediate, both because it is prepared without an acidic catalyst, and therefore has broader application, and because it can be prepared directly to suit a particular application, thus obviating the need for dilution with monomeric FA to produce coatings, etc.

Important as the economic advantages of the new gamma alumina process are, the most important feature of the new process is likely to be the fact that it makes practical the production of compression molding compounds based on FA resins, thus greatly broadening the fields of application for these excellent resins.

Injection Molding Process

(Continued from page 9)

temperature are determined by the injection pressure and heater controls. During the plunger forward time there is packing into the mold the same as in conventional molding (A-B). But as soon as the plunger returns the gate is sealed at a pressure and temperature higher than in conventional molding but along the same cooling line that will give a good molding. Since this packing period is much shorter than in conventional molding the residual strains in the molded piece are much less.

CONCLUSIONS

The plastic temperature and pressure in the mold are the main quantities that control the quality of the injection molded article. These two quantities are determined by some complex arrangement of the primary control variables listed in Table I. Therefore it would be of value to the injection molding machine operator to know and be able to control directly the pressure and temperature in the mold. Since this is not possible at present the authors have tried to analyze the various controls and mechanisms available to determine how these controls are related to the pressure and temperature in the mold. It has also been shown how the quality of the molded article is dependent upon the pressure and temperature in the mold. It is the belief of the authors that a more exact knowledge of what happens during the injection molding cycle will aid the molder in solving many of his injection molding problems.

BIBLIOGRAPHY

1. The Role of Pressure, Temperature, and Time in the Injection Molding Process.
   G. D. Gilmore and R. S. Spencer.
   Modern Plastics, April, 1950.
2. Pressure Gauge For Injection Molding.
   F. E. Towsley.
3. Equation of State for Polystyrene.
   R. S. Spencer and G. D. Gilmore.
   J. App. Phys. 20, 502-506, (June, 1949).
4. The Injection Molding Cycle.
   G. D. Gilmore.
   India Rubber World, March, 1952.
5. Temperature Measurements in Injection Molding Machines.
   C. E. Beyer and R. B. Dahl.
   Modern Plastics, Sept., 1952.
6. Behavior of Granulated Polymers Under Pressure.
   R. S. Spencer, G. D. Gilmore, and R. M. Wiley.
   J. App. Phys. 21, 527-531, June, 1950.

Elastomeric Vinyls

(Continued from page 57)

gates assists greatly in getting uniform plasticizing action with the resultant improvement in appearance of the molded piece.

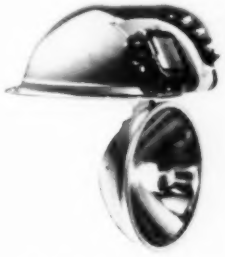
The screw pre-plasticizing type of injection molding machine presents many advantages as a means of molding vinyls. Among these advantages are relative freedom from thermal degradation, more uniform plasticization, increased plasticizing capacity, and faster molding cycles. Material savings can also be obtained by molding directly from pre-blends, rather than granular materials.

ACKNOWLEDGEMENT

Thanks are due to Mr. R. M. Hershey, who obtained much of the experimental data, and to the Hoover Company for permission to publish the information contained in this paper.

PROFIT HAS MANY FORMS

when the material is DUREZ



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Vinyl Floor Coverings

(Continued from page 37)

of floor coverings, price stability of these materials is very important. Agricultural products, such as drying oils, which are used in large quantities by the floor covering industry are always subject to wide price fluctuations. For example linseed oil prices have varied from 10 to 38 cents per pound during the past ten years. Obviously, such conditions in the price structure of raw materials make future planning risky, to say the least. Like most synthetics, vinyl resin prices are much more stable, and material costs can be predicted with reasonable accuracy. Furthermore, the price trend of vinyls has been downward, and it is expected that this trend will continue.

One more incentive for the growth of vinyl floor coverings is the relatively low capital investment required for its manufacture. While vinyl processing equipment cannot be termed inexpensive, it does not approach the cost of that required for linoleum manufacture. Since the vinyl resin binder is supplied ready for use and since no long stoving periods are needed for curing, the size of plants and amounts of equipment are materially reduced.

In five years vinyl floor coverings have grown from almost a curiosity to an annual volume of 20,000,000 square yards. The motivating forces behind this growth,—quality of product, versatility of application and ease of processing, are making vinyls a leading contender for the top volume line in the resilient flooring industry.

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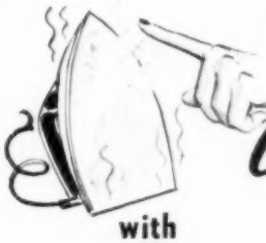

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